Vol. XXIII, Part III

September, 1953

THE INDIAN JOURNAL OF AGRICULTURAL SCIENCE

Issued under the authority

of

The Indian Council of Agricultural Research

सत्यमेव जयते

Annual subscription
Rs. 15 or 23s. 6d.

Price per part
Rs. 4 or 6s. 6d.

PUBLISHED BY THE MANAGER OF PUBLICATIONS, DELHI.
PRINTED BY THE GOVERNMENT OF INDIA PRESS, CALCUTTA, INDIA,
1953

ICAR. 5. XXIII, III
880.

CONTENTS

Vol. XXIII, Part III

(September, 1953)

The Publications Committee of the Indian Council of Agricultural Research, India, takes no responsibility for the opinions expressed in this Journal

Original articles

ORIGINAL ARTICLES

RESPONSE CURVES AND THE PLANNING OF EXPERIMENTS

By D. J. Finney*, University of Oxford

(Received for publication on 23 April 1953)

(With five text-figures)

In the planning of agricultural experiments, the choice of the set of treatments to be compared often receives too little attention. Great care may be exercised in what is generally regarded as the 'design' of the experiments, namely choice of number of replicates, of systems of confounding, for factorial treatments, of Latin squares or randomized blocks or incomplete blocks of many kinds. At the same time, an agronomist may propose to test a particular set of treatments without giving due thought to whether, in the light of existing information, this set is the best possible for his purpose ; a statistician will often proceed to design an experiment for a set of treatments proposed to him, without troubling to look critically at the type of result likely to be produced and at the advantages and disadvantages of alternative sets.

Funds for agricultural research are always limited, and are usually much less than most research workers think necessary. Efficient use of these funds is therefore important to the progress of research. In general terms, a programme of experimentation with one objective means that less can be spent on other objectives : if experimenters spend their resources in the study of low levels of fertilizer application, they have less to spare for the study of high levels, and vice versa ; if they concentrate on fertilizers, this must to some extent reduce the resources available for investigating other aspects of agronomic practice, although adoption of factorial design permits some escape from this limitation. In this situation, to undertake experiments without careful discussion of the method of experimentation and the value of the results to be obtained is deplorable. Three questions should invariably be asked before an experiment is begun :

What information already exists on the questions under examination ?

In the present state of agricultural research, does the additional information likely to accrue from a new experiment justify expenditure on this rather than on some other topic ?

Are the treatments to be tested and the experimental design the best that can be chosen for providing answers to the questions ?

I am not arguing that all experimental programmes should be dictated by immediate economic needs. There is a place for experiments that explore beyond

* F. A. O. Statistical Expert, temporarily attached to the Indian Council of Agricultural Research.

the range of what is of direct practical value, but even for these the economic considerations are by no means lacking : the division between ' of no practical importance but worth while ' and ' fantastic ' is determined by what work at any one moment holds out a reasonable hope of future value—value in the broadest sense and as judged by those who have the direction of research funds. Here I am not concerned with these few exceptional experiments, but with the great majority of agricultural field trials whose aim is to discover ways of increasing national production and the prosperity of the cultivator in the fairly near future. Recently I have participated in many discussions of agronomic experiments (especially for fertilizers) for use in India, though the interest of the problems is not restricted to India. In the paper that follows, I have summarized some of these problems and have made suggestions for general experimental policy in relation to them. My object, however, is not to give final decisions on all points but to encourage in agricultural research workers a more critical attitude towards the experiments they plan and the treatments they test. I have not hesitated to express a personal opinion, but I do not expect it to be accepted as statistical dogma ; I believe that I am providing a policy suitable for most experiments, but special circumstances may make selection of treatments on a different basis very desirable.

1. Response curves

The selection of treatments to be tested can often be improved by consideration of *response curves*, the curves relating the average yield (or other measured characteristic) of a crop to the numerical value of some controllable factor such as manuring or spacing. A typical response curve for the average yield of a crop in relation to the amount of fertilizer applied is shown in Fig. 1. As the amount of fertilizer is increased, the yield increases, but the rate of increase declines for the higher amounts. In any one experiment, the regularity of this relationship will be obscured by the inherent variability of crops and soils ; the average of a number of experiments should show a reasonable approximation to such a curve, and experiments should normally be planned on the assumption that this will be so. For very high levels of fertilizer application, the effect on the crop may actually be harmful, and in consequence yields will decline again ; thus excessive amounts of nitrogen, particularly in the absence of adequate moisture, may depress the yield and produce a continuation of Fig. 1 in which the curve falls again. For practical purposes, particularly in a country where large dressings of fertilizers are seldom used, attention can usually be restricted to the rising portion of the curve, as there is little likelihood of going beyond this in experiments employing reasonable levels of application (see Section 7, Optimal dressings and maximum yields). The response curve may vary from soil to soil, and even from year to year, but in the planning of new experiments even a rough average curve can be a great help.

For the cultivator, the most attractive dressing of a fertilizer is that which offers the greatest net profit. That amount depends upon the relative prices of fertilizer and crop, and so will change from season to season (but perhaps less markedly than some would suppose). If the price of fertilizer is expressed in terms of the

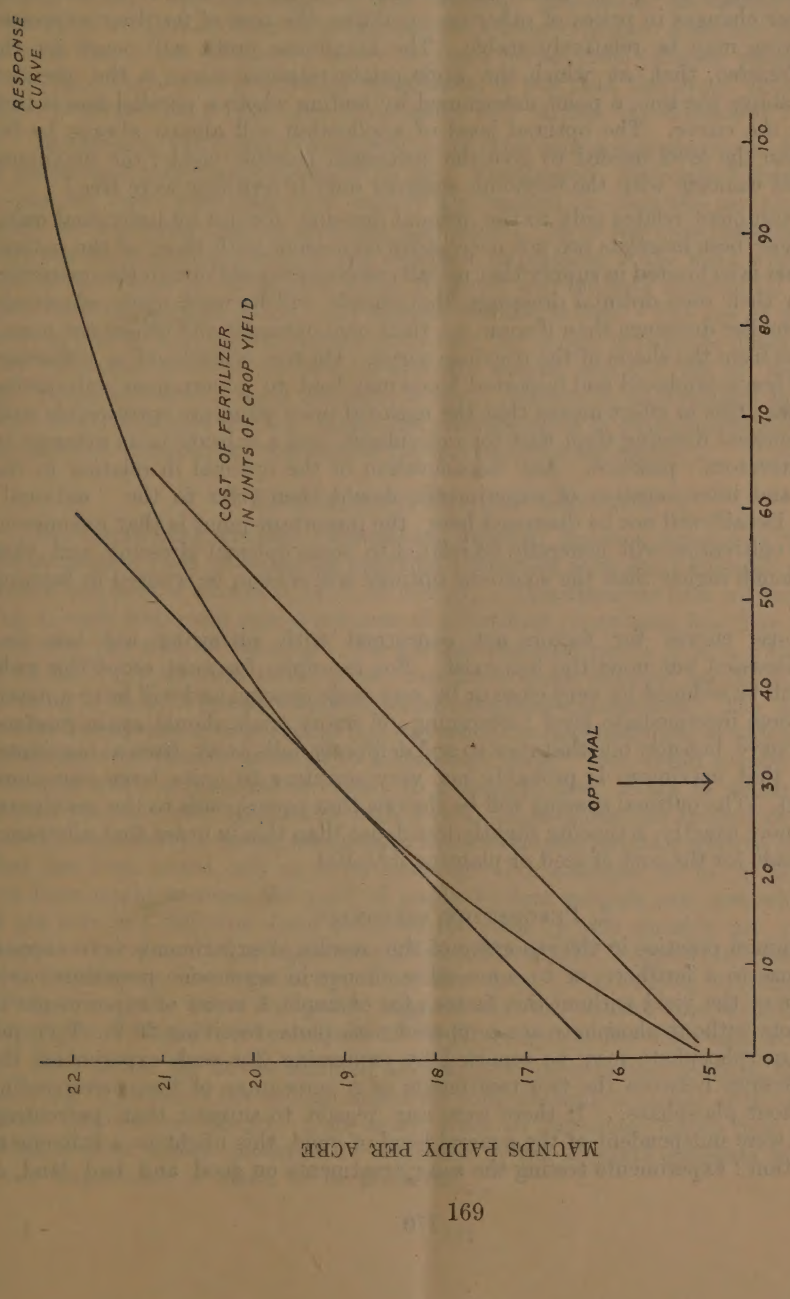

Fig. 1 : A typical fertilizer response curve, showing also the cost of fertilizer and the tangent determining the optimal dressing

weight of crop of equal value (e.g. one maund of sulphate of ammonia might cost 1·5 maunds paddy), the cost of any dressing may be represented by a straight line through the origin in Fig. 1. Since changes in food prices will tend to be associated with similar changes in prices of other commodities, the cost of fertilizer expressed in crop units may be relatively stable. The maximum profit will occur for the *optimal dressing*, that at which the appropriate response curve is the greatest distance above the line, a point determined by finding where a parallel line is tangential to the curve. The optimal level of application will almost always be far smaller than the level needed to give the maximum possible yield : the maximum yield would coincide with the economic optimal only if fertilizer were free !

This argument relates only to the optimal dressing for use by individual cultivators, whose best interests are not necessarily coincident with those of the nation. If a fertilizer is so limited in supply that not all cultivators could obtain the quantities needed for their own optimal dressings, that supply will be used more effectively if all use smaller dressings than if some use their own optimals and others use none ; this is clear from the shape of the response curve. On the other hand, a difference in price of home-produced and imported foods may lead to government subsidizing of fertilizers ; this in effect means that the national price structure corresponds with a higher optimal dressing than that for individuals, and a subsidy is an attempt to adjust cultivators' practice. Any consideration of the optimal in relation to the planning and interpretation of experiments should then refer to the 'national' optimal. Details will not be discussed here : the important point is that recommendations to cultivators will generally be related to some optimal dressing, and that dressings much higher than the economic optimal will seldom be wanted in farming practice.

Response curves for factors not concerned with manuring are less frequently discussed but none the less exist. For example, for most crops the yield per acre will be reduced by very close or by very wide spacing and will have a maximum at some intermediate level ; averaging of many trials should again produce a smooth curve, but now one that rises to and definitely falls away from a maximum (although that maximum is probably not very sensitive to quite large variations in spacing). The optimal spacing will be the one that corresponds to the maximum yield or, more exactly, a spacing slightly less dense than this in order that allowance may be made for the cost of seed or planting material.

2. Percentage responses

A common practice in the reporting of the results of experiments is to express the response to a fertilizer, or to some other change in agronomic procedure, as a percentage of the yield without this factor ; for example, a series of experiments in which plots without phosphate are compared with plots receiving 20 lb. P_2O_5 per acre as superphosphate may be reported by expressing (for each experiment) the mean difference between the two treatments as a percentage of the corresponding yield without phosphate. If there were any reason to suppose that percentage responses were independent of the general level of yield, this might be a convenient simplification : experiments testing the same treatments on good and bad land, or

on different varieties of the same crop, would tend to show the same percentage responses whatever the absolute magnitudes were. In reality, however, this is far from the truth. An experiment on land seriously deficient in phosphate may give a low yield without addition of phosphate and a large response ; a similar experiment on land that is not deficient is likely to give a better yield without phosphate and a response that, even in absolute magnitude, is less than the first. Expression of these responses as percentages accentuates still further the difference.

In assessing the value of manuring, or of other agronomic practices, knowledge of percentage responses is of very little use. Fortunately, the control yields used as a base for these percentages are usually also quoted, so that the percentages may easily be converted back to absolute magnitudes. A 10 per cent response to fertilizer can be of neither practical nor economic importance if the yield without fertilizer is low, but an equal percentage response will indicate substantial economic gains from the fertilizer if the yield without fertilizer is high. The use of percentage responses may be intended as a simplification, but in fact it tends to obscure reality. The cultivator sells his produce by absolute weight, and the cost of the nation's food imports depends upon absolute weight : evaluation of fertilizers in terms of percentage responses neither assists the interpretation of experiments nor has any direct relationship to the economy of the cultivator or the nation.

3. Responses per pound of fertilizer

In summarizing fertilizer experiments, another common practice is to express the increase in yield obtained by applying a fertilizer as so much for each pound per acre of sulphate of ammonia, of N, or of P_2O_5. As is apparent from an inspection of Fig. 1, each additional pound per acre of a fertilizer contributes less than its predecessors to the yield of the crop. The average response per lb. N to a total dressing of 40 lb. N per acre will thus be less than the average response per lb. N to a total dressing of 20 lb. N per acre applied under comparable conditions. The only sound reason for expressing responses in this way would be that responses to widely different dressings were thereby reduced to a standard basis. This would require that the response curve approximated closely to a straight line. Since in reality the curvature becomes very marked at high levels, the response per pound of fertilizer based upon a heavy dressing may grossly undervalue this fertilizer relative to another that has been tested only at a low dressing. For example, 20 lb. N per acre in one form might increase the yield of paddy by four maunds per acre while 80 lb. N per acre in a different form increased the yield by nine maunds per acre. The responses per pound of nitrogen would be 16 lb. and 9 lb. respectively, yet this does not demonstrate the superiority of the first form ; the existing evidence on the nitrogen response curve for paddy suggests that the second form would also give a response of about four maunds to 20 lb. N per acre rather than only 2·2 maunds.

Once again the device adopted as a simplification in fact obscures the truth, and may be seriously misleading unless the total dressing is quoted at the same time as the response per pound. Once again, since no advantage comes from this form of expression, direct quotation of responses in the absolute amounts that are of basic importance is much to be preferred.

4. Standardization of responses

There is nevertheless a real need for a method of averaging the results of different fertilizer experiments in which possibly very different levels of application have been under test. The device discussed in the last section is an attempt to do this by reducing each response to a standard basis. The faults in it can be avoided if, instead of standardizing by direct proportionality, a standardization curve that approximates to the shape of the true response curve can be used. Crowther and Yates [1941] have indicated how this can be done. The procedure is illustrated in more detail with respect to Indian conditions in the paper ' The use of fertilizers on food grains ' [Yates, Finney and Panse, 1953]; the essential feature is that the response to any dressing is divided by a numerical factor associated with that dressing, in order to give an estimate of the response to a chosen standard dressing.

5. Inclusion of controls

In fertilizer experiments, inclusion of a *control* treatment (defined as the absence of fertilizer) is usually desirable, even when the direct response is not the main question. An experimenter who wishes to compare the merits of nitrogen for paddy supplied either as sulphate of ammonia or as groundnut cake may argue that he knows nitrogen to be beneficial and that therefore all he need do is to compare the two forms. He may, therefore, test 20 lb. N per acre in each form and omit any test of plots without nitrogen. If a clear difference between the two forms of nitrogen appears, he can draw satisfactory conclusions from it. If no difference appears, however, he is left uncertain whether the two forms are about equally effective or whether the particular soil and seasonal conditions were such that the crop failed to respond to nitrogen; in the second case, his experiment provides no evidence on which to judge between the forms. Only by having available records from plots that received no nitrogen can the difficulty of interpreting the experiment be resolved. A similar situation arises in many other types of experiment, such as tests of time of application of nitrogen or methods of placement of phosphate, in which failure to include plots without fertilizer may prevent the experimenter discriminating between absence of any response and absence of any difference between the treatments he is investigating. Of course, in a factorial experiment in which two or more fertilizers are being tested in various combinations, the zero level of each should normally be included in combination with all levels of the other (but see Section 9, Inter-relationship of two factors).

If the chief object of an experiment is to test different levels of one fertilizer whose effectiveness is well established, with a view to determining the optimal level, omission of any test of the control or zero level may be permissible. Even this should seldom be done, because existing evidence on the region of the response curve between zero and the lowest level tested is rarely so strong, or interest in this region so slight, that the information provided by the control would be of negligible value.

6. Choice of levels of application

In an experiment to test the value of a fertilizer, at least two levels of application will be included. These may be zero and a single non-zero level or possibly two non-zero levels. For the experiment to be useful, there must be a reasonable interval between the two levels. An attempt to distinguish experimentally between the effects of 40 lb. N and 45 lb. N per acre, or even between zero and 5 lb. N per acre, is very little use, since the difference in crop yield will almost certainly be small by comparison with the experimental errors unless many good experiments are averaged. The choice of levels to be tested in any experiment should be made in relation to the purpose of that experiment, remembering that no trustworthy information can be obtained outside the range of levels tested. For example, from an experiment in which zero and 30 lb. N per acre are tested, no inference can be drawn about the effect of 60 lb. N per acre (except that the response would probably not be less than that to 30 lb. N and would not exceed twice this amount). If a test of zero and 60 lb. N per acre has been made, the results are a little more useful for inferring the consequences of intermediate levels, though even there little more can be said about the response to 30 lb. N than that it would probably exceed one-half that to 60 lb. N. The results of an experiment testing only two levels are of very limited value, except as estimating the difference between these two particular levels.

If something is known about the form of the response curve, results of experiments on zero and one other level can be used to give an idea of responses to different levels (see Section 4, Standardization of responses). This may lead to a fairly reliable inference for levels below that of the experiments but extrapolation to higher levels is risky. Consequently, in exploratory experiments in which many factors have to be included each at two levels only, or in series of simple experiments on cultivators' fields which may not contain enough plots to permit the test of more than two levels for a fertilizer, the levels chosen should usually be zero and a quantity about equal to or a little higher than the optimal. Of course, the optimal will not in fact be known, but usually experimenters will have some idea of it; if they believe that, under current conditions, the optimal for paddy is about 20 to 25 lb. N per acre, then the level chosen for experiment might be 25 lb. N or 30 lb. N, either being more useful than, say, 60 lb. N. Unless there is strong reason to think that circumstances will encourage the widespread use of higher levels by the cultivators, to experiment upon 60 lb. N per acre would be very unwise.

Whenever possible, experimenters should consider testing more than two levels of application, for only so can they obtain direct evidence on the response curve. The best scheme usually is to have zero and two other levels or possibly zero and three other levels. Very rarely is there any advantage in having more than three non-zero levels, and the practice of including a large number of levels is to be discouraged as leading to definitely less precise conclusions. Provided that the optimal level can with certainty be included in the range of levels tested, an experiment having five plots at each of four levels (including zero) will almost certainly give better information on the optimal than would one having two plots at each of ten

levels, as may be shown by statistical theory. The choice between three and four levels can be made primarily on grounds of convenience, with special reference to whether other factors in the experiment are being tested at three levels or at two and four levels (technical considerations of experimental design show advantages for having all factors in an experiment either at three levels or at two and four: see Section 10, Number of factors). Once again the actual levels depend upon the purpose of the experiment. If the chief interest lies in estimating the optimal dressing, the levels should be chosen in relation to any existing information on this optimal. The fact that an experiment is to be done is an indication that complete information is lacking, but the wise experimenter will formulate some kind of guess of what the optimal will be in order to choose levels from which the most precise revised estimate can be formed. Clearly the total range of doses should be chosen to include the optimal. If the guessed value for the optimal is x and three levels are to be tested, the quantities zero, x, and 2x would be a good choice. There are theoretical reasons for believing that levels slightly larger than these are to be preferred to anything smaller, and if the guessed value x is too high the loss of precision will be less serious than if it is too low. Consequently the choice of 0, $1\frac{1}{4}$x and $2\frac{1}{2}$x may be in general rather better. If four levels are to be tested, the right procedure is not to make the highest level greater than before, but to divide the same interval into narrower steps. Thus 0, 0·8x, 1·6x, and 2·4x would be a good choice.

These recommendations are not intended to tie experimentation closely to the prices ruling at a particular moment; they should be regarded as general guidance. In a programme of experiments continued over several years, the same levels should be retained unless great changes of price occur. For a crop that is subject to violent alterations in price from year to year (e.g. cotton), a relatively wider region of the response curve must be investigated in order to ensure that all reasonably likely positions of the optimal are well within it. A given amount of experimentation will then supply less reliable information on responses to any particular level of application, this being the price that must be paid for the insistence that *some* information be obtained on a greater range of levels. The number of levels actually subjected to test may then need to be increased, either by having more in each experiment or by allocating different sets of levels for trial in different experiments. For crops with more stable prices, however, the upper limit of $2\frac{1}{2}$ times the approximate optimal will usually be a sufficiently high level for trial to satisfy even those experimenters who advocate the use of heavy dressings.

It has here been assumed that zero will be one of the levels tested. When the optimal is known in advance to be high, the case for excluding zero and testing three or four non-zero doses may be strong. The advantage of this is that the levels can be concentrated more closely about the optimal, so that any faulty assumption about the exact shape of the response curve is less serious, but this same concentration also has adverse effects on precision. Only rarely in agricultural experiments should zero be excluded.

Similar considerations arise in experiments to determine the optimal level of other practices, such as spacing between rows or between plants. As mentioned

in Section 1, Response curves, the optimal spacing will be practically coincident with the spacing for maximum yield, but an important difference is introduced because a zero level is meaningless. Once again three or four different spacings should be included ; a careful balance should be struck between having them sufficiently far apart to show appreciable yield differences and having them sufficiently close together to give good information in the neighbourhood of the maximum. Once again a good guess by the experimenter may enable him so to choose his spacing levels as to ensure that the results of his experiment are as precise as possible in their estimation of the ideal spacing.

7. Optimal dressings and maximum yields

Experimenters often find some conflict of interest between the study of levels of fertilizer application in the neighbourhood of the optimal economic level and that of levels sufficient to give the maximum possible yield. A claim may be put forward that the maximum yield and the conditions governing it are absolute properties of the crop, and of primary agronomic interest, whereas the economically optimal level of application of a fertilizer is subject to day-to-day fluctuations in prices. Special experiments designed to investigate the conditions in respect of various factors under which the yield will be maximum are therefore said to be required. There are, however, grave objections to this policy. In the first place, the maximum is by no means easy to discover. The form of Fig. 1 suggests that a slight increase in yield may continue over a very considerable range of increases in dressing. The level at which the yield begins to decline again, because of harmful effects of fertilizer, will often be far above the levels that have been well studied in past experimentation, and, over a wide interval below this, yields will have been increasing slowly. It may well be true that, for many Indian crops and soils, application of potassic fertilizer is unnecessary, but potash may nevertheless give slight benefits and at any rate produce no harmful effects up to very substantial levels of application. Thus the knowledge of what is reasonable farming practice is little guidance towards what factors should be studied in an investigation of maximum yields. A very extensive experimental programme would be needed if any thorough search for maximum yields were to be made.

In fact, the argument that the economically optimal levels of agronomic factors are subject to variation is much less important than at first appears. A change in prices will certainly alter the optimal dressings of fertilizers for any crop, but the changes that occur in any short term of years are likely to be relatively small. Moreover, the effect of some deviation from the true optimal, whether too little or too much is applied, is relatively small in respect of net profit. The cultivator requires information on results to be expected from fertilizer dressings in the neighbourhood of those that will prove most profitable, and information on how to produce the greatest possible yields is no substitute for this. Moreover, since the budget for agricultural research must be limited, information on maximum yields can be obtained only at the expense of information on matters of immediate practical importance : the dressings that should be experimentally tested are entirely different for the two purposes. Some will say that information on maximum possible yields

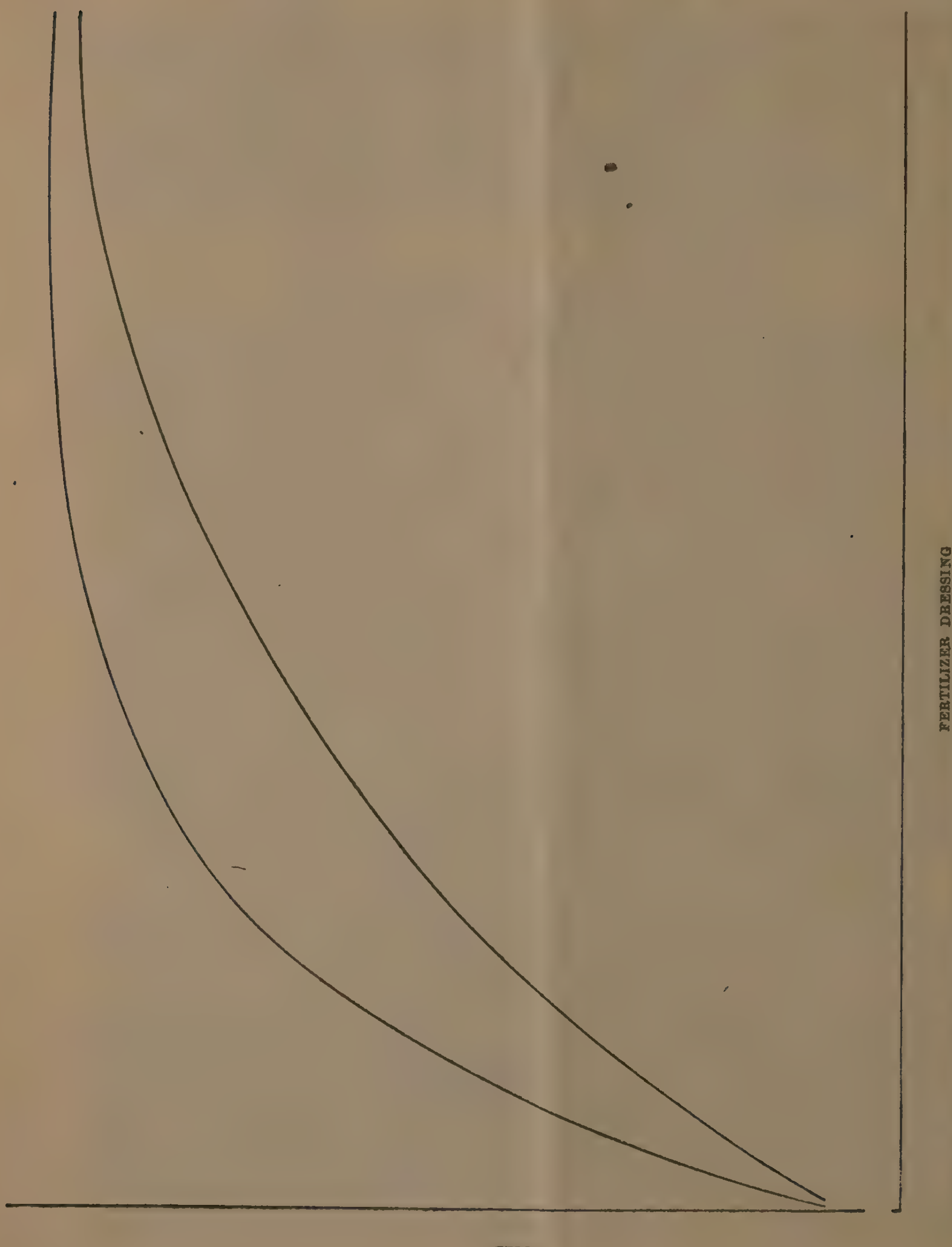

Fig. 2. Illustration of response curves for two forms of fertilizer showing small yield difference for large dressings but large difference for small dressings.

is required, because in time of emergency no expense will be spared in increasing agricultural production. This can never be true, for, even though instructions are given that vastly greater efforts are to be put into agriculture, limitations of labour and of supplies will always exist. National emergency, indeed, may lead to shortage of fertilizer rather than abundance and therefore may make more acute the need for economic utilization. Knowledge of what can be done by great increases in fertilizer applications, or great intensifications of cultivation and weeding that require much additional labour, is of a very limited practical value. The effect of a national emergency is only to alter violently the values that are placed upon these factors in agronomic practice, and not to eliminate entirely their real cost. Experimentation on levels of factors far removed from those at present economically desirable is justified only in so far as sudden changes in national economy may make them desirable, and not because of some fundamental importance of maximum yields.

8. Comparisons of forms of fertilizer

One important class of fertilizer experiments is that for comparing alternative sources of the same nutrient, with a view to assessing the relative values of the alternatives for agricultural use. Different sources of nitrogen, whether inorganic or organic, may be equated chemically on the basis of their nitrogen content; the agricultural values of equal weights of nitrogen supplied as sulphate of ammonia, as ammonium nitrate, and as groundnut cake, however can be compared only by field experiments. The answers obtained will in general be different for different crops and on different soils, since they depend upon the availability of nitrogen to the crop and the rate at which the crop requires to assimilate it.

In planning experiments of this kind, the argument too often used is that very heavy dressings ought to be included, in order to make sure that substantial responses are obtained for comparison. The experimenter perhaps accepts the argument of Section 5, Inclusion of controls, on the need for including a 'no nitrogen' treatment in a comparison between sources of nitrogen for wheat, and he then proceeds to test also 80 lb. N per acre from each of the three sources mentioned above. Unfortunately, this may conceal or present misleadingly the very differences that interest him. With nitrogen, for example, if sufficiently large dressings are supplied in any moderately available form, the crop may be able to obtain all that it can use; by testing high levels of application, the experimenter may fail to discover important differences that exist at low levels. This situation is illustrated by Fig. 2. Another possibility with some fertilizers is that for small dressings two different forms are about equally effective, but that the maximum responses obtainable from large quantities are very different. Since these large quantities are probably in any event far beyond the economic level, comparison of the fertilizers at high levels will suggest a difference in value, when for practical purposes they are about equally good (see Fig. 3). As in Section 7, Optimal dressings and maximum yields, the moral is that the levels chosen for experiment should be within the range of practical interest. For reasons similar to those emphasized in Section 6, Choice of levels of application, at least two non-zero levels of each form of fertilizer should be tested as well as zero. For example, in comparing three forms of nitrogen, the treatments

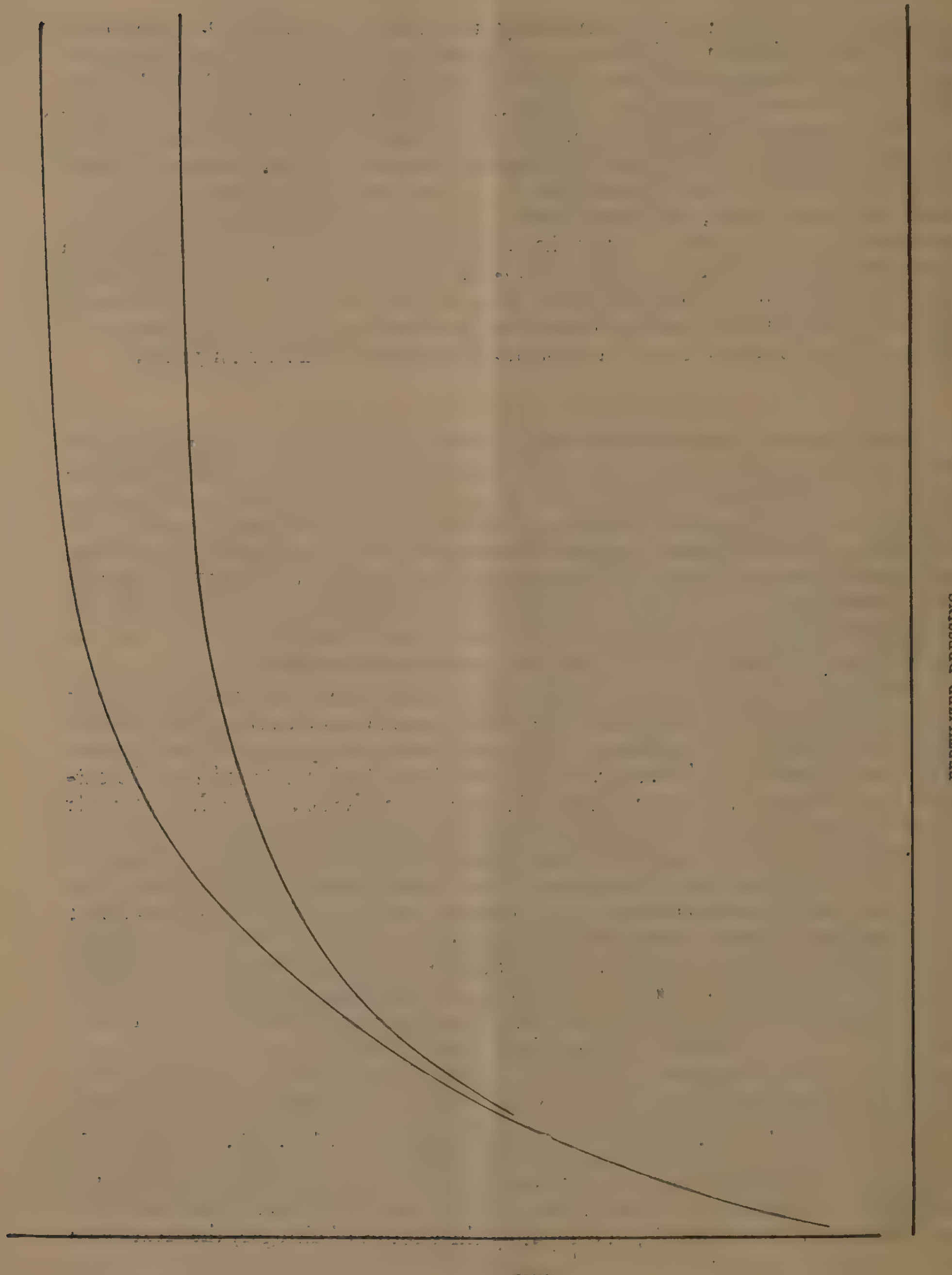

Fig. 3. Illustration of response curves for two forms of fertilizer showing large yield difference for large dressings but small difference for small dressings.

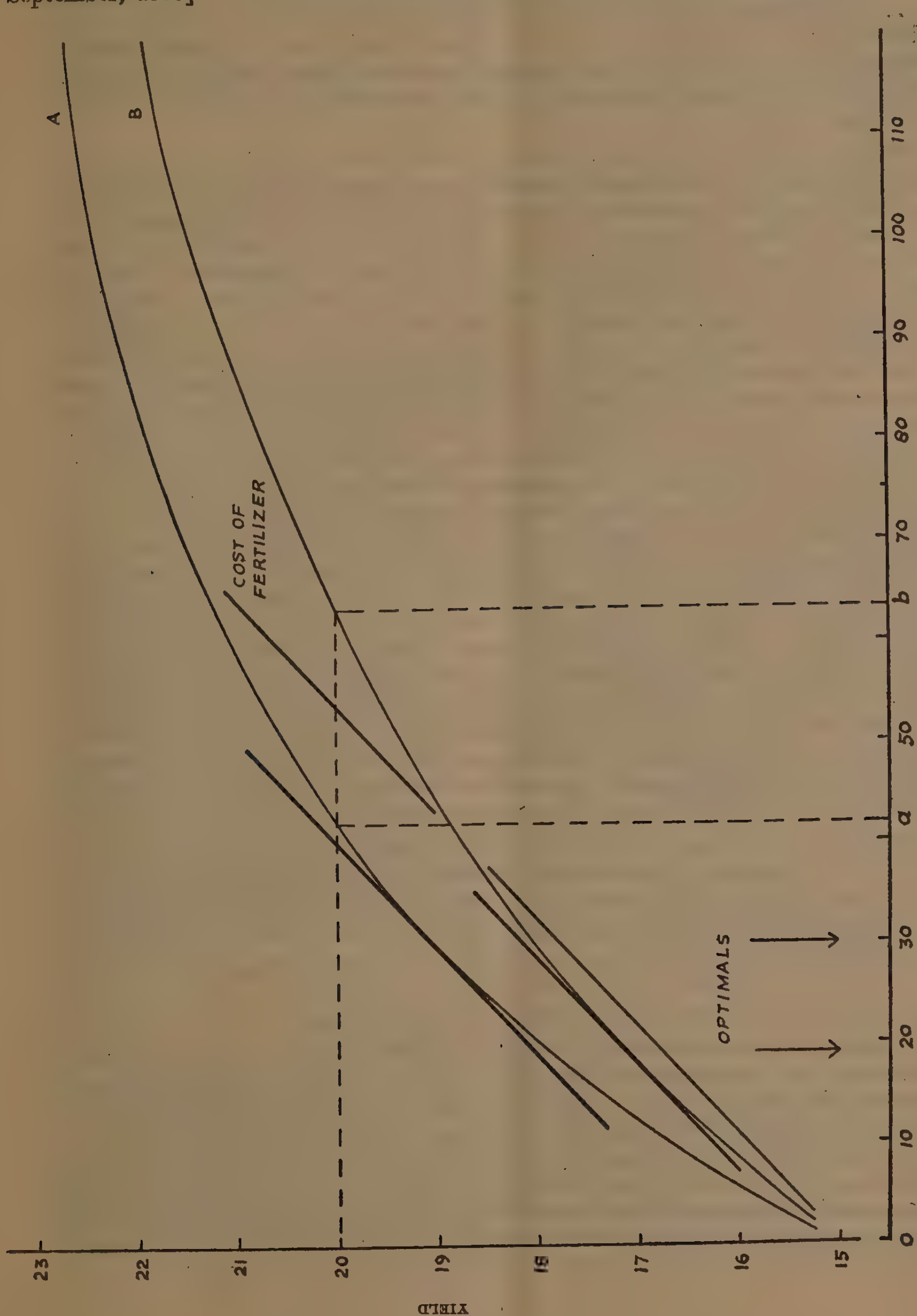

Fig 4. Response curves for two forms of fertilizer A and B, such that 1 unit of A is as effective as 1·5 units of B. Constructions are shown for:

(*i*) Equivalent dressings, Oa and Ob; Ob=1·5 Oa at whatever yield the comparison is made;

(*ii*) Optimal dressings, in this instance 30 for A and 19 for B.

might well be zero and single and double levels of each form. If many different forms have to be compared with one standard, a permissible economy of treatments may be effected by using two non-zero levels of the standard and only one of each of the others.

The comparison between two forms of fertilizer can be made in three ways, each of which is important in some circumstances. These are illustrated in Fig. 4. The obvious way, and that usually employed, is to examine the yields obtained with, say, equal amounts of nitrogen per acre applied in two different forms. From the point of view of evaluating the production obtainable from existing fertilizer supplies, however, a horizontal comparison in Fig. 4 is perhaps more useful than the vertical. This leads to estimation of how much of one form is equivalent to (*i.e.*, produces the same response as) unit amount of the other.* For some fertilizers, this ratio of equivalent amounts will be approximately constant throughout the response curve, and Fig. 4 has in fact been drawn for the case of one unit of the first form being as effective as 1·5 units of the second. The third form of comparison is that between optimal levels for the two forms. In choosing levels for an experiment, the question : Which of these aspects is of the greatest interest ? arises. If the first, then equal weights of nitrogen should be given in each form, say 20 lb. per acre and 40 lb. per acre. If the second, a better comparison will be obtained if some preliminary guess at the relative effectiveness can be used to choose amounts giving approximately equal responses ; in Fig. 4, for example, 20 lb. N and 40 lb. N per acre for the first form would be best accompanied by 30 lb. N and 60 lb. N per acre of the second. If the comparison of optimal dressings is the matter of primary interest, the levels tested should ideally be chosen separately for the two forms in accordance with Section 6, Choice of levels of application. In practice, when any one of the three ways of looking at the results of an experiment may in fact be wanted, the common procedure of equalizing the test levels on the basis of nitrogen content is probably a fairly good compromise, at least provided that the forms under investigation do not differ very widely in effectiveness.

Essentially the same problems arise in investigating alternative methods of application of a fertilizer. For example, if surface broadcasting of superphosphate is to be compared with drilled application, two response curves need to be considered and questions of relative effectiveness and differences in optimal levels once again enter the discussion.

9. Inter-relationship of two factors

When two factors are to be considered simultaneously, the concept of a response curve needs to be generalized to that of a *response surface*. For example, if nitrogen and phosphate are under test, an axis to the north might be used to represent the weight of N supplied per acre, an axis to the east to represent the weight of P_2O_5, and an axis vertically from the page the yield (Fig. 5) ; the mean yields for different combinations of N and P_2O_5 would then lie on a surface. The simplest situation is that in which the response to either fertilizer is unaffected by the amount of the

* The problem here is essentially the same as that of biological assay [Finney, 1952].

other supplied ; a typical response surface of this kind might show the following yields of paddy :

		lb. N per acre			
		0	25	50	75
lb. P_2O_5 per acre	0	10·0	14·8	17·4	19·0
	20	12·0	16·8	19·4	21·0
	40	13·4	18·2	20·8	22·4
	60	14·5	19·3	21·9	23·5

When the responses are independent in this way, the optimal level of either factor will be the same whatever the amount of the other.

Any deviation from this independence of response is usually described as an *interaction* of the effects of the two factors involved. The fact that the response to a particular dressing of one fertilizer may change in magnitude with changes in the amount of another is clearly of great agronomic and economic importance, so that experiments need to be carefully planned in order to detect interactions, whether positive (response to one factor increased by increasing the amount of the other) or negative. Sometimes an interaction is very obvious : on certain soils, nitrogenous fertilizer may have scarcely any effect on yield, but, if phosphate is given, that itself increases the yield substantially as well as producing conditions in which the crop responds well to nitrogen. An interaction, however, can be much less easily detectable yet still large enough to be of practical value. Just as the cost of a single fertilizer is represented by a straight line in Fig. 1, so the cost of two fertilizers can be represented in the three-dimensional diagram of the response surface by a plane, with two slopes corresponding to the prices of the two components. The optimal combination of dressings is then determined by the point on the response surface at which a parallel plane is tangential to the surface.

If no large interaction is expected, but well-distributed information on the response surface is wanted in order that the average responses to the two factors can be examined and good search made for any signs of interaction, a complete factorial scheme of treatments should be used : levels of each factor, chosen in accordance with the recommendations of Section 6, Choice of levels of application, should be tested in all combinations. To use all combinations is certainly not essential to the validity of the experiment ; in the absence of any compelling reason to the contrary, this is a convenience and an advantage, but if strong indications exist that certain combinations are of no practical interest the design may be modified so as to exclude them. Some experimenters like to regard the choice of levels of two fertilizers as a choice of the level for one and of the ratio between the two. This is no harm in itself, since any pair of dressings can alternatively be specified by one dressing and a ratio, but its advantages may be doubted since recommendations

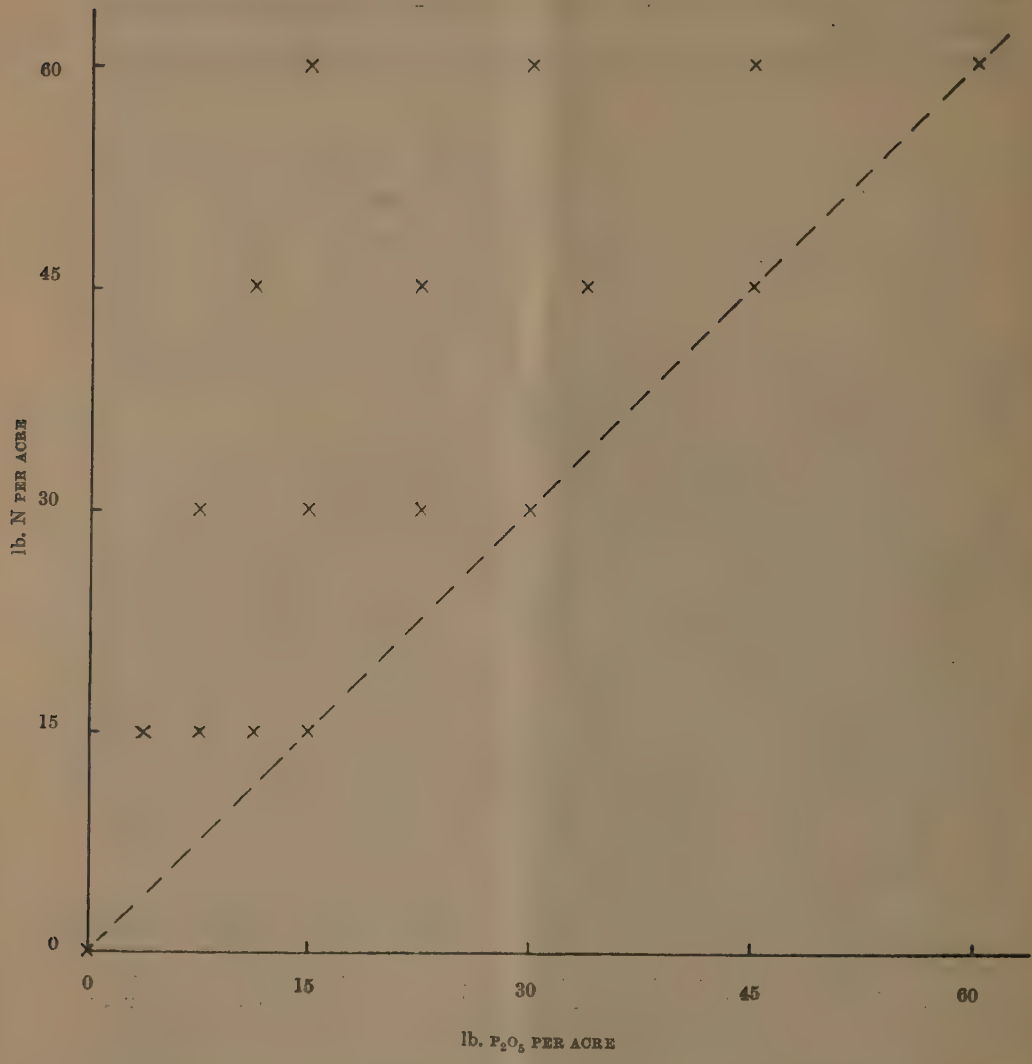

Fig. 5. Representation of levels of application of two fertilizers used simultaneously ; if yield were recorded on an axis vertically upwards from the page, a response surface would be formed.

The points marked are the combinations of levels resulting from adoption of the levels of one fertilizer and the ratios of it to the other discussed in the text. Note that, although the combinations are restricted to those for which the ratio is 1 : 1 or greater, the observations are very unevenly spread over the triangular sector of the plane.

on manuring are most usefully given in terms of actual quantities. Moreover, description of results in terms of ratios tends to induce an attribution of some special sanctity to certain ratios of plant nutrients. Under certain conditions, a 2 : 1 ratio of N and P_2O_5 may be excellent for a particular crop, but if fertilizer prices fall there is no guarantee that the same ratio would remain optimal at the higher dressings that then become economic ; indeed, if phosphate were to become much cheaper while the price of nitrogen remained unaltered, the proportion of P_2O_5 would almost certainly need to be increased. Admittedly the ratio required is in some measure determined by the ratio of the uptakes of nutrients by the crop, but reserves in the soil complicate this and prevent a particular ratio being shown up on the response surface by a sharp ridge of superior yields. Judgement of dressings to be used in experiments, of course, must not be biased by the fact that mixtures of fertilizers in certain proportions are at present available to cultivators : if price changes or new research show that other proportions are desirable, the supply can presumably be adjusted to suit.

Emphasis on ratios has sometimes led experimenters to adopt a ' complete factorial ' scheme of quantities of one fertilizer and ratios. One recent example is of tests of 0, 15, 30, 45, 60 lb. N (sulphate of ammonia) in combination with P_2O_5 (superphosphate) such that the ratios of N to P_2O_5 are 4 : 1, 2 : 1, 4 : 3, and 1 : 1. The argument was that past experience had shown that the dressing of P_2O_5 ought never to exceed that of N, and that therefore attention should be restricted to combinations in which N : P_2O_5 was at least 1 : 1. The combinations of levels chosen have the serious defect that they concentrate too much effort on very small quantities of phosphate at the expense of the higher ones, so giving a very unequal cover of the possibilities in the relevant section of the N, P_2O_5 diagram (see Fig. 5). The addition of $3\frac{3}{4}$ lb. P_2O_5 or $7\frac{1}{2}$ lb. P_2O_5 per acre, the two smallest amounts that accompany 15 lb. N per acre, is too small to have an effect detectable by an experiment of moderate size, and even $11\frac{1}{4}$ lb. P_2O_5 and 15 lb. P_2O_5 per acre are so small and close together as to be likely to produce almost equal yields. Moreover, no tests of nitrogen in the absence of phosphate were made, so that the effects of the two components could not be distinguished. A better scheme would have been to write down all combinations of 0, 20, 40, 60 or 0, 15, 30, 45, 60 lb. N per acre with equal amounts of P_2O_5 and then to strike out from the experiment each of the six or ten in which the level of P_2O_5 exceeded that of N.

Even the modification of a complete factorial scheme in the manner described above is rarely wise, for it involves the assumption not only that the ratio N : P_2O_5 should at present be 1 : 1 or greater but also that changes in prices will continue to keep the optimal combination in this region. The ratio experiments used to introduce this discussion were in fact wrongly based on this assumption. Careful tabulation and examination of the results suggested that the best combination would be a small amount of nitrogen and rather more phosphate ; because large quantities of phosphate were tested only in combination with large quantities of nitrogen, however, the dominant response to phosphate was liable to suggest that heavy dressings of nitrogen were also desirable !

Despite what has been said in criticism of experiments based on ratios, they might sometimes be useful. One of the virtues of the ordinary factorial experiment is that not only does it provide information on responses to the combinations tested but, by interpolation, it permits inferences to be drawn about other combinations. This is possible in so far as the response surface, expressed in terms of the two factors, has a fairly simple form, and especially if interactions are small or negligible. Any response surface can alternatively be expressed in terms of the level of one factor and the ratio : if there were reason to believe that it would then be simpler in form than before, the choice of treatments criticized adversely above would be advantageous. A statement that 'the response to nitrogen depends upon the ratio of nitrogen to phosphate' is not in itself a good reason, for if this be true it is equally true that the response to nitrogen depends upon the amount of phosphate. For the satisfactory choice of experimental treatments, the nature of the dependence is what matters ; in fact, if the response to nitrogen were completely independent of the ratio yet the ratio itself affected yield, the testing of all combinations of a set of levels of N and a set of ratios would be ideal. It should not be forgotten that results of ordinary factorial experiments can always be rearranged in terms of ratios, so that an experimenter who wishes to study this matter may first examine evidence of past experiments in order to see what light they throw on it ; if after this he considers that the response surface can be more simply specified in terms of the ratio, he will rightly plan his experiment accordingly. He should be sure to include a sufficiently wide range of ratios and might find 1, 2 and 4 units of one fertilizer in combination with ratios of 2 : 1, 1 : 1, and 1 : 2 a good choice.

A slightly different problem can arise in choosing levels of two factors when both relate to the same characteristic of plant growth. Spacing of plants is an example. For tuber crops, and others in which single plants are separately set in the ground, experiments are sometimes done in which the treatments are all combinations of three inter-row spacings with three intra-row spacings. Now the primary effect of spacing on a crop is likely to come from the average area per plant : whether each plant has 72 sq. in. or 144 sq. in. for growth is much more important than whether 144 sq. in. is arranged as 12 in. $\times$ 12 in., 16 in. $\times$ 9 in. or even 24 in. $\times$ 6 in. The usual method of specifying treatments may give two very extreme areas per plant and others that are nearly equal but have different linear dimensions. One possible modification is to omit from the complete factorial set of treatments the extremes that are of little interest. An alternative worth considering is to choose as the two factors the area per plant and the inter-row spacing ; all combinations of three levels of each are written down, and the intra-row spacings obtained by division. Even with this alternative, a small area per plant in combination with wide spacing between rows may require a ridiculously close spacing within rows, and this treatment should then be omitted. Essentially the same problem arises in experiments concerned with frequency of irrigation, amount of irrigation water on any one occasion, and total amount of water supplied.

The ideas of this section can be extended to experiments in which three or more factors are to be considered simultaneously.

10. Number of factors

Many experiments suffer from the fault that too few factors are included. As explained in Section 6, inclusion of particular levels of a factor is possible only by omitting or giving less attention to alternative levels. Often, however, an entirely new factor can be introduced into an experiment without affecting the value of the experiment in respect of the original factors—or even with enhancement of this value because the factors are tested under more diverse conditions. Suppose an experiment is to test the nine combinations of nitrogen and phosphate each at three levels. The smallest experiment likely to be chosen would be three randomized blocks of nine plots, and possibly six blocks would be preferred. With either scheme, an additional factor at three levels can be introduced into the experiment, by *confounding* certain unimportant interactions, without causing any less information to be obtained on nitrogen and phosphate. None but an unimaginative experimenter would have difficulty in thinking of a third factor that he would like to include : in practice, there is likely to be keen competition between the interests of three levels of potash, three varieties, three spacings, three levels of irrigation, and so on. To rest content with the experiment on two factors only is extravagant and wasteful of resources.

The possibility of including additional factors often occurs when all the original factors are at two and four levels or all are at three levels. The experimenter should usually consider the desirability of filling his experiment to capacity with factors ; for example, he should regard an experiment with 64 plots as an encouragement to use six factors at two levels, and should be reluctant to leave it with only three or four factors. By the device of fractional replication, as many as seven or eight factors at two levels can be tested on 64 plots and five factors at three levels on 81 plots. Details of how this is to be done may require to be settled by a professional statistician, but the experimenter should always be alive to the possibility.

11. Design

In planning for successful experiments, all the matters raised in earlier sections should be considered before technical details of design (such as number of replicates and type of confounding) are settled. Their discussion will usually proceed concurrently with discussion of design, since decisions on each point may to some extent be modified by others. The purpose of this paper is to persuade experimenters that rational decisions can be taken on questions of numbers and magnitudes of levels to be tested, and that good experimentation is achieved only when these are given attention as careful as is becoming customary for questions relating to other aspects of design.

Summary

After an explanation of the role of the response curve in the interpretation of experiments, both agronomically and economically, and discussion of alternative ways of reporting responses, many suggestions relating to the choice of treatments for agronomic experiments have been advanced.

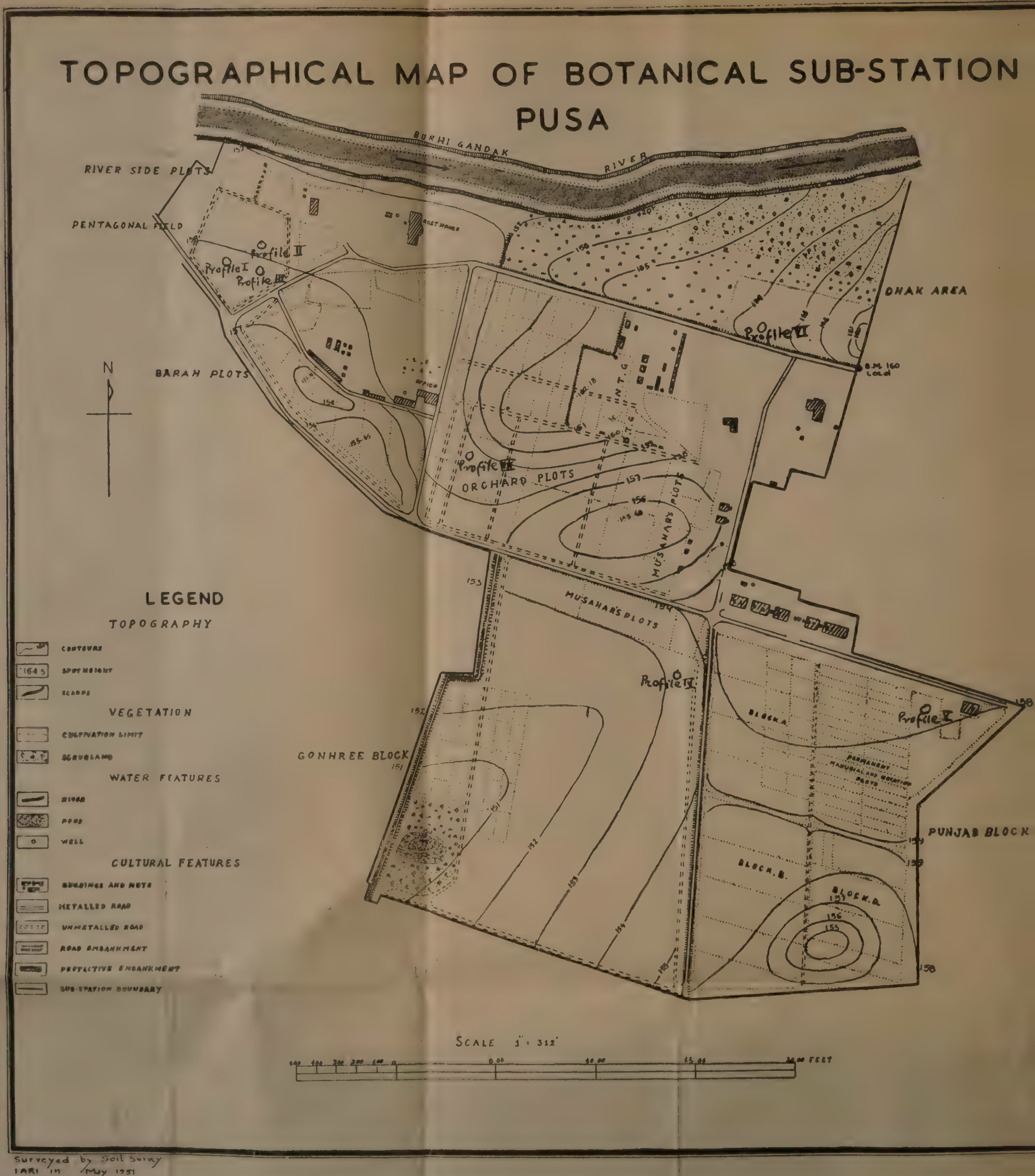

Fig. 1 Map of Botanical Sub-Station, Pusa

STUDIES ON THE CHARACTERISTICS OF SALINE AND ALKALINE PATCHES IN THE SOILS OF PUSA

By S. V. Desai and Abhiswar Sen, Indian Agricultural Research Institute, New Delhi

(Received for publication on 15 September, 1952)

(With one text-figure)

THE soils of Pusa Estate in North Bihar, District Darbhanga, are loamy in texture and are characterised by very high contents of calcium carbonate. Pits dug up at different places in the fields show that the soils are deposits on sand of an old river bed. At about eight feet depth, undisturbed deposits of sand of a former marine bed are observed and at 10 feet, marine shells are found in large quantities. In spite of the moderate rainfall of the area (about 44 inches), alkaline and saline patches appear in winter in cultivated fields. These patches have very poor growth of crops in them. On newly formed patches, germination of the seed is very poor and if at all there be any germination, the plants do not thrive well and often die out before attaining maturity. The roots of the plants on these patches become brittle. They shed root hairs and are seldom able to function normally.

Sen [1917] observed saline patches under big trees and bamboo groves and found alkalinity decreasing with distance from the trunk of the tree. The Pentangular area of the estate had always been under heavy crops and was observed to be highly infested with salts. Howard [1925] made extensive attempts to reclaim the area with the help of flooding with water and incorporation of large amounts of organic manures with the soil. Basu [1930] found that the first three inches of a field of badly damaged sugarcane (Jhilli fields) contained more than 2·0 per cent of soluble salts, most of which was sodium sulphate. These patches developed in spite of application of organic manures or artificial fertilisers.

It may be fair to assume that the origin of salts in the soils of this region is due, along with other well-known causes, to excessive weathering of the soil minerals under alternate arid and humid tropical conditions of soil atmosphere. The presence of a large excess of $CaCO_2$ in the soil may be helping the process. The rainfall at Pusa cannot be considered to be so high as to remove all the salts to any great depth and under these conditions, the salts may be moving from surface to subsoil and *vice versa*, going down with the rains and accumulating at the surface under dry weather conditions. Profuse transpiration of water by heavy crops under such conditions may also be a factor effecting ascendence of soluble salts to the surface.

Under such conditions, when the drainage is efficient, very little salinity will develop as a result of accumulation of salts at any depth, and the vertical distribution of salts in the profile is expected to be somewhat uniform. When the soils are less sandy and proper facilities for drainage do not exist, the salts have only to move to lower depths and it is less likely that they will be completely washed out from the fields. Salts can then accumulate under favourable dry weather conditions, to form the observed patches.

During the present investigation, soils of three profiles from the Pentangular field, one normal and two alkaline of one alkaline profile from the Gonhri fields, of one from the uncultivated area near the former European club, of one from the cultivated field from the Dhab area near the Gondak river and of one from the Orchard plot I B have been examined. It is expected that the results of examination of the soils (Fig. 1) will provide additional information regarding the development of alkaline patches in the area.

Materials and methods

Soils

Morphological description of the soils of the profiles collected are given in Table I.

Table I

Morphologioa' description of the soils of the Pusa profiles

Depth in inches	Description
	Profile I. Pentangular field, alkaline area
0— 6	Dark grey, loam, structureless, presence of grass roots
6—12	Grey, loam, structureless, whitish when dry
12—22	Dark grey, loam, presence of white ants, single grain structure, few plant-roots present
22—34	Whitish grey, sandy, structureless, getting darker with depth
34—40	Sandy loam, alternate layers of light and grey soil, more moist than above
40—50	Uniformly grey, loam, heavier than above
50—54	Ash colour, loam, quite moist
54—below	Grey sand, blue and yellow streaks, almost pure sand between stratified layers
	Profile II. Pentangular field, alkaline area
0—12	Grey, loam, loose, penetration of plant roots, structureless, whitish grey when dry
12—18	Grey, loam, hard and compact. more clayey than the first layer, crumby, yellow streaks, fewer roots than the first layer
18—55	Grey, sandy loam, yellow and blue streaks, structureless, loose, stratification visible below 27 inches
55—below	Grey, sandy soil, stratified layers, slightly more moist than the top layer, blue and yellow streaks, glistening sand between layers

TABLE I—(*contd.*)

Morphological description of the soils of the Pusa profiles

Depth in inches	Description
	Profile III. Pentangular field, normal area
0—20	Grey, loam, loose penetration of roots, structureless, whitish grey when dry, slightly hard and compact at lower depths
20—50	Grey, sandy loam, blue and yellow streaks, loose and structureless, slight stratification throughout the depth of the layer
50—56	Grey, sandy loam, more moist than above, blue and yellow streaks, stratified layers, structureless
56—61	Grey, loam, more clayey than above, blue and yellow streaks compact, structureless
61—67	Sandy loam, blue and yellow streaks, visible stratification, structureless, occasional occurrences of glistening sand
	Profile IV. Gonhri field, alkaline area
0— 6	Whitish grey, friable, presence of plant roots
6—12	Dark grey, less friable than above
12—20	Dark grey, loam, loose and structureless, yellow and brown streaks
20—27	Brownish grey, sandy loam, yellow streaks, structureless
27—32	Grey, sandy loam, compact, more moist than above
32—39	Brownish grey, sandy loam, presence of white ants, yellow and brown streaks
39—53	Dark grey, loam, structureless, stratified layers
53—60	Dark grey, more clayey and moist than above
	Profile V. Uncultivated area near the former European Club
0—13	Grey, loam, plenty of roots, pieces of bricks between 4″ and 13″, falls to powder on rubbing
13—40	Grey, loam, grey colour lighter than above, penetration of roots up to 27″, singled grained, more compact downwards
40—47	Whitish grey, loose, silty, structureless

TABLE I—(*concld.*)

Morphological descriptions of the soils of the Pusa profiles

Depth in inches	Description
	Profile VI. Cultivated area, Dhab land near the river
0—14	Grey, sandy loam, abundance of yellow and brown streaks, penetration of roots, structureless
14—28	Grey, sandy soil, yellow and brown streaks at 14″-18″, at 18″-28″ almost pure sand, penetration of roots, structureless
28—42	Grey, loam, single grain structure, brown streaks, roots present up to 28″
42—70	Whitish grey, sandy loam, brown and blue streaks, loose
70—80	Grey, clay loam, plenty of bluish tinge, abundance of conches, more moist than above, structureless
	Profile VII. Orchard plot IB
0—17	Dark grey, sandy loam, occurrence of pea-shaped nodules, loose, structureless
17—35	Grey, sandy soil, whitish towards the bottom, crotorinas occur at 17″-24″, same as the top layer, loose
35—54	Grey, sandy loam, blue and yellow streaks, occasional concretionery nodules, loose and structureless
54—72	Grey, loam, brown and yellow streaks, structureless, more moist than above, compact

Methods

The mechanical analysis of the soils were carried out by NaCl dispersion [Puri, 1929]. CO_2 figures obtained by Schrotter's method [Newth, 1911] were converted to $CaCO_3$.

Soils from the alkaline as well as the normal profiles were washed with 40 per cent alcohol [Piper, 1947] before leaching with normal neutral ammonium acetate solution [Schollenberger and Dreiselbis, 1930] for total base exchange capacity and exchangeable Mg, K and Na. Exchangeable Ca was determined by Hissink's method [Hissink, 1923] as modified by Tiurin [Tiurin, 1927].

Analysis of the water extracts were carried out by the usual methods [A. O. A. C. 1945]. The combination of acid and basic radicals in the same were done by the method adopted by Leather [1902].

Results

The results of the mechanical analysis of the soils are given in Table II.

TABLE II

Mechanical composition, pH, salinity and $CaCO_3$ contents of the soils of the Pusa profiles

(expressed as per cent on moisture-free basis)

Depth in inches	Mechanical fractions				pH	Total soluble salts	$CaCO_3$
	Coarse sand (2·0—0·2 mm.)	Fine sand (0·2—0·02 mm.)	Silt (0·02—0·002 mm.)	Clay (0·002 mm.)			
	Profile I. Pentangular field, alkaline area						
0— 6	13·26	24·68	52·37	9·69	7·77	0·641	41·84
6—12	6·81	18·94	68·09	6·16	8·49	0·199	45·27
12—22	6·23	16·47	63·99	13·22	8·47	0·187	46·81
22—34	13·41	48·57	35·90	2·15	8·91	0·074	32·23
34—40	6·75	61·76	23·84	7·65	8·85	0·108	29·60
40—50	25·52	47·16	25·65	1·67	8·69	0·064	26·85
50—54	21·99	36·01	37·90	4·10	9·00	0·096	33·80
54—below	19·28	45·72	33·90	1·10	8·91	0·070	31·93
	Profile II. Pentangular field, alkaline area						
0—12	9·70	29·32	53·60	7·93	7·55	0·279	32·96
12—18	12·06	9·20	52·60	26·93	8·22	0·203	44·66
18—55	12·56	26·46	44·77	16·62	8·27	0·089	46·91
55—below	7·51	20·43	43·74	28·32	8·41	0·096	39·77
	Profile III. Pentangular field, normal area						
0—20	5·88	25·64	55·20	13·28	7·80	0·103	45·22
20—50	5·24	40·28	46·48	7·80	7·98	0·064	49·30
50—56	18·32	55·89	21·36	4·43	8·13	0·070	36·21
56—61	11·24	26·65	53·16	8·95	10·21	0·622	40·67
61—67	13·91	39·24	41·63	5·22	8·51	0·066	47·10

TABLE II—(*contd.*)

Mechanical composition pH salinity and $CaCO_3$ contents of the soils of the Pusa profiles

Depth in inches	Mechanical fractions				*p*H	Total soluble salts	$CaCO_3$
	Coarse sand (2·0—0·2 mm.)	Fine sand (0·2—·02) mm.)	Silt (0·02—0·002) mm.)	Clay (0·002) mm)			
Profile IV. Gonhri field, alkaline area							
0— 6	9·18	29·76	47·49	13·67	9·00	0·286	41·42
6—12	0·00	15·66	71·15	13·85	9·11	0·129	49·23
12—20	8·90	9·13	59·81	22·16	9·28	0·081	49·79
20—27	0·84	8·82	73·62	16·72	8·91	0·087	53·14
27—32	8·15	3·18	76·75	11·92	8·83	0·057	49·47
32—39	6·27	23·40	62·50	7·78	8·39	0·054	45·13
39—53	5·54	1·73	73·10	19·72	8·13	0·053	54·09
53—60	3·64	6·70	70·66	19·00	8·41	0·083	52·86
Profile V. Uncultivated area							
0—13	21·87	25·14	30·65	5·74	7·28	0·134	34·39
13—14	17·94	25·58	45·96	11·10	7·60	0·113	39·22
40—47	7·36	57·66	29·74	5·24	7·87	0·056	38·05
Profile VI. Cultivated area							
0—14	21·87	46·59	23·60	7·94	7·63	0·034	28·04
14—28	77·40	12·72	7·83	2·05	7·58	0·045	22·53
28—42	11·45	30·59	44·19	13·77	7·02	0·049	28·51
42—70	12·00	31·60	46·40	10·00	7·52	0·051	33·71
70—80	18·54	27·04	37·95	16·47	7·70	0·064	33·52
Profile VII. Orchard plot I B							
0—17	25·99	43·19	24·77	6·05	7·38	0·091	35·59
17—35	24·73	58·01	14·65	2·61	7·78	0·084	36·08
35—54	11·45	64·19	20·04	4·32	7·80	0·063	35·42
54—72	11·23	23·77	55·22	9·78	7·87	0·056	47·74

It can be seen that the soils of practically all the profiles increase with depth with the exception of those of Gonhri field, where the *p*H values decrease and of the cultivated Dhab area where they remain practically the same throughout all the depths examined. Same is true of the content of soluble salts which tend to decrease with depth except in the Dhab area where it increases with depth. A remarkable exception is in the case of the normal profile in the Pentangular area, where maximum salinity is observed at 56-61 in. depth.

Results of determination of water soluble constituents base exchange capacity and exchangeable bases are given in Tables III and IV.

TABLE III

Saline constituents of the soils of the Pusa profiles

(*expressed as per cent on moisture-free basis*)

Depth in inches	CO_3	HCO_3	Cl	SO_4	Ca	Mg	K	Na
Profile I. Pentangular field, alkaline area								
0—6	—	—	0·014 (NaCl-0·023)	0·337 (Na_2SO_4-0·269)	0·053	0·010	0·006	0·111
6—12	0·005	0·032	0·009 (NaCl-0·015)	0·091 (Na_2SO_4-0·140)	0·003	0·004	0·003	0·064
12—22	0·005	0·035	0·008 (NaCl-0·014)	0·073 (Na_2SO_4-0·117)	0·003	0·007	0·002	0·050
22—34	0·007	0·028 ($NaHCO_3$-0·011)	0·005 (NaCl-0·009)	0·014 (Na_2SO_4-0·022)	0·002	0·005	0·002	0·015
34—40	0·005	0·032 ($NaHCO_3$-0·040)	0·010 (NaCl-0·016)	0·032 (Na_2SO_4-0·051)	0·002	0·001	0·002	0·037
40—50	0·007	0·026 ($NaHCO_3$-0·033)	0·005 (NaCl-0·009)	0·012 (Na_2SO_4-0·020)	0·002	0·002	0·001	0·020
50—54	0·009 (Na_2CO_3-0·003)	0·026 ($NaHCO_3$-0·036)	0·005 (NaCl-0·009)	0·020 (Na_2SO_4-0·032)	0·002	0·002	0·002	0·027
54—below	0·007	0·025 ($NaHCO_3$-0·034)	0·004 (NaCl-0·007)	0·006 (Na_2SO_4-0·010)	0·001	0·002	0·002	0·016
Profile II. Pentangular field, alkaline area								
0—12	—	0·036	0·014 (NaCl-0·023)	0·136 (Na_2SO_4-0·134)	0·109	0·006	0·003	0·053
12—18	—	0·038	0·011 (NaCl-0·018)	0·086 (Na_2SO_4-0·119)	0·007	0·044	0·002	0·046
18—55	—	0·036	0·007 (NaCl-0·012)	0·017 (Na_2SO_4-0·021)	0·007	0·003	0·002	0·011
55—below	—	0·036	0·007 (NaCl-0·012)	0·021 (Na_2SO_4-0·019)	0·008	0·004	0·002	0·011

TABLE III—(*contd.*)

Saline constituents of the soils of the Pusa profiles

Depth in inches	CO_3	HCO_3	Cl	SO_4	Ca	Mg	K	Na
Profile III. Pentangular field, normal area								
0—20	—	0·038	0·010 (NaCl-0·017)	0·020 (Na_2SO_4-0·026)	0·008	0·003	0·002	0·015
20—50	0·006	0·019	0·006 (NaCl-0·011)	0·017 (Na_2SO_4-0·025)	0·004	0·003	0·002	0·012
50—56	—	0·034 ($NaHCO_3$-0·002)	0·006 (NaCl-0·010)	0·006 (Na_2SO_4-0·009)	0·006	0·004	0·002	0·008
56—61	0·060 (Na_2CO_3-0·074)	—	0·021 (NaCl-0·034)	0·334 (Na_2SO_4-0·495)	0·005	0·004	0·002	0·206
61—67	—	0·034	0·008 (NaCl-0·012)	0·002	0·005	0·004	0·002	0·005
Profile IV. Gonhri field, alkaline area								
0—6	0·015 (Na_2CO_3-0·004)	0·074 ($NaHCO_3$-0·101)	0·008 (NaCl-0·013)	0·114 (Na_2SO_4-0·184)	0·002	0·002	0·007	0·104
6—12	0·009	0·037 ($NaHCO_3$-0·050)	0·004 (NaCl-0·007)	0·024 (Na_2SO_4-0·038)	0·002	0·002	0·002	0·031
12—20	0·008	0·025 ($NaHCO_3$-0·033)	0·004 (NaCl-0·006)	0·007 (Na_2SO_4-0·012)	0·001	0·002	0·007	0·016
20—27	0·005	0·034 ($NaHCO_3$-0·030)	0·004 (NaCl-0·007)	0·006 (Na_2SO_4-0·009)	0·002	0·001	0·007	0·014
27—32	0·007	0·029 ($NaHCO_3$-0·022)	0·005 (NaCl-0·009)	0·005 (Na_2SO_4-0·008)	0·002	0·002	0·008	0·013
32—39	0·003	0·031 ($NaHCO_3$-0·014)	0·005 (NaCl-0·009)	0·006 (Na_2SO_4-0·009)	0·003	0·001	0·007	0·011
39—53	0·003	0·033 ($NaHCO_2$-0·001)	0·002 (NaCl-0·003)	0·007 (Na_2SO_4-0·011)	0·003	0·002	0·007	0·008
53—60	0·002	0·048 ($NaHCO_3$-0·022)	0·004 (NaCl-0·006	0·006 (Na_2SO_4-0·010)	0·007	0·001	0·004	0·011
Profile V. Uncultivated area								
0—13	—	0·043	0·010 (NaCl-0·016)	0·037 (Na_2SO_4-0·036)	0·010	0·005	0·002	0·013
13—40	—	0·034	0·007 (NaCl-0·012)	0·034 (Na_2SO_4-0·032)	0·009	0·004	0·002	0·015
40—47	—	0·032	0·007	—	0·006	0·005	0·002	—

TABLE III—(*contd.*)

Saline constituents of the soils of the Pusa profiles

Depth in inches	CO_3	HCO_3	Cl	SO_4	Ca	Mg	K	Na
Profile VI. Cultivated area								
0—14	—	0·018	0·005	..	0·006	0·001	0·001	—
14—28	—	0·026	0·004	0·001	0·006	0·003	0·001	—
28—42	—	0·029	0·004	tr.	0·006	0·003	0·001	—
42—70	—	0·029	0·005	0·001	0·006	0·004	0·002	—
70—80	—	0·034	0·007	0·001	0·013	0·002	0·002	—
Profile VII. Orchard plot I B								
0—17	—	0·049	0·007 (NaCl-0·002)	0·004	0·013	0·005	0·002	0·001
17—35	—	0·044	0·006 (NaCl-0·007)	0·007	0·012	0·004	0·001	0·003
35—54	—	0·033	0·008	0·001	0·011	0·002	0·002	tr.
54—72	—	0·028	0·008 (NaCl-0·001)	0·002	0·007	0·004	0·001	0·001

TABLE IV

Base exchange capacity and exchangeable bases in soils of the Pusa profiles (expressed as milli-equivalents per cent on moisture-free basis)

Depth in inches	Base exchange capacity	Exchangeable bases			
		Ca	Mg	K	Na
Profile I. Pentangular field, alkaline area					
0— 6	8·22	6·61	2·17	0·23	1·52
6—12	4·16	1·69	1·02	0·32	1·52
12—22	10·46	5·07	2·43	0·41	2·92
22—34	3·58	1·25	0·94	0·12	3·78
34—40	6·96	1·99	1·01	0·16	6·37
40—50	3·17	0·92	0·41	0·22	3·19
50—54	2·05	1·11	0·24	0·35	3·64

4 AR/53

TABLE IV—(*contd.*)

Base exchange capacity and exchangeable bases in soils of the Pusa profiles

Depth in inches	Base exchange capacity	Exchangeable bases			
		Ca	Mg	K	Na
Profile II. Pentangular field, alkaline area					
0—12	9·25	5·38	3·95	0·02	1·64
12—18	9·10	4·82	3·81	0·07	1·40
18—55	5·25	0·35	6·78	0·03	0·25
55—below	7·75	2·77	6·06	0·01	0·14
Profile III. Pentangular field, normal area					
0—20	4·10	4·60	0·99	0·24	1·22
20—50	3·90	1·57	1·68	0·05	1·18
50—56	2·90	2·05	1·19	0·25	1·15
56—61	4·30	5·10	1·36	0·79	1·18
61—67	2·65	1·92	1·00	0·22	1·21
Profile IV. Gonhri field, alkaline area					
0— 6	10·26	2·32	2·03	0·21	6·98
6—12	10·41	2·09	2·44	0·23	6·21
12—20	17·02	4·38	2·29	0·15	13·11
20—27	13·54	2·99	1·68	0·19	8·78
27—32	8·78	2·98	2·31	0·12	3·62
32—39	6·98	4·02	2·06	0·23	2·01
39—53	16·44	9·69	4·29	0·21	2·78
53—60	17·23	10·46	4·03	0·33	2·98

TABLE IV—(*contd.*)

Base exchange capcity and exchangeable bases in soils of the Pusa profiles

Depth in inches	Base exchange capacity	Exchangeable bases			
		Ca	Mg	K	Na
Profile V. Uncultivated area					
0—13	6·60	8·67	0·78	0·35	0·05
13—40	3·95	5·07	0·78	0·06	0·32
40—47	3·40	3·39	0·97	0·13	0·67
Profile VI. Cultivated area					
0—14	6·50	7·20	0·94	0·13	0·65
14—28	2·30	4·20	1·10	0·30	0·38
28—42	7·50	9·72	3·80	0·11	1·06
42—70	6·35	7·37	2·01	0·03	0·89
70—80	8·45	7·68	3·22	0·38	2·28
Profile VII. Orchard plot IB					
0—17	3·80	5·04	1·92	0·10	0·66
17—35	2·75	4·09	2·05	0·06	0·55
35—54	3·10	3·64	2·61	0·49	0·81
54—72	3·75	3·84	1·65	0·05	0·97

Effect of leaching the soils with water

As the saline and alkaline patches appear during winter and disappear during monsoon allowing *kharif* crops to grow well, it was thought probable that the rains washed down the soluble salts and some sort of natural reclamation of these patches occur during the monsoon. To study the changes, brought forth by successive leaching of the soils with water, the soils of the Profiles I and IV were shaken and leached with water (1 : 5). The *p*H values and the exchangeable bases of the soils

were determined after each washing. The water extracts were analysed for total soluble salt contents. The results are given in Tables V and VI. It is clear that successive leaching with water results in lowering of salinities and also of pH values in some cases of the soils of the alkaline profiles. The process also brings about marked decrease in the contents of exchangeable Na in the soils.

TABLE V

Effect of successive leaching with water (1 : 5) on reaction and salinity of the soils of the alkaline profiles

Depth in inches	pH from			Salts per cent by		
	1st washing	2nd washing	3rd washing	1st washing	2nd washing	3rd washing
Profile I. Pentangular field, alkaline area						
0— 6	7·77	7·63	7·86	0·641	0·318	0·077
6—12	8·49	8·11	8·45	0·199	0·106	0·051
12—22	8·47	8·79	7·93	0·187	0·081	0·044
22—34	8·91	8·16	8·17	0·074	0·049	0·026
34—40	8·85	8·03	8·28	0·108	0·074	0·033
40—50	8·69	7·96	8·20	0·064	0·054	0·030
50—54	9·00	8·15	8·18	0·096	0·072	0·032
54—below	8·91	8·26	8·26	0·070	0·053	0·026
Profile IV. Gonhri field, alkaline area						
0— 6	9·00	8·96	8·38	0·286	0·091	0·055
6—12	9·11	8·45	8·26	0·129	0·068	0·051
12—20	9·28	8·79	8·11	0·081	0·061	0·038
20—27	8·91	7·94	8·25	0·086	0·056	0·036
27—32	8·83	8·69	8·25	0·057	0·055	0·034
32—39	8·39	8·11	8·51	0·054	0·048	0·030
39—53	8·13	8·25	8·18	0·053	0·043	0·035
53—60	8·41	7·67	8·37	0·083	0·049	0·034

TABLE VI

Effect of successive leaching with water (1 : 5) on the content of exchangeable bases in the soils of the alkaline profiles

Depth in inches	Exchangeable bases (m.e.)				Exchangeable bases (m.e.)			
	Soil	1st residue	2nd residue	3rd residue	Soil	1st residue	2nd residue	3rd residue
Profile I. Pentangular field, alkaline area								
	Calcium				*Sodium*			
0—6	6·61	6·02	6·21	6·64	1·52	1·45	1·21	1·01
6—12	1·69	2·83	2·94	3·21	1·52	1·04	1·02	0·98
12—22	5·07	8·02	8·22	8·48	3·92	1·98	1·45	0·94
22—34	1·25	2·32	3·14	4·14	3·78	1·74	1·46	0·92
34—40	1·99	6·73	5·82	6·12	6·37	3·22	1·82	0·88
40—50	0·92	2·69	3·01	3·82	3·19	1·69	1·42	0·87
50—54	1·75	4·86	4·78	5·01	5·23	2·34	1·49	0·94
54—below	1·11	1·79	2·27	1·98	3·64	1·49	0·59	0·45
	Magnesium				*Potassium*			
0—6	2·17	1·98	1·45	1·01	0·23	0·22	0·19	0·19
6—12	1·02	1·02	0·78	0·82	0·32	0·31	0·18	0·14
12—22	2·43	2·12	1·74	1·12	0·41	0·32	0·17	..
22—34	0·94	1·04	1·03	0·98	0·12	0·22	0·19	0·20
34—40	1·01	0·98	0·69	0·54	0·16	0·25	0·20	0·19
40—50	0·41	0·21	0·22	0·32	0·22	0·27	0·22	0·18
50—54	0·32	0·32	0·41	0·31	0·28	0·24	0·24	0·19
54—below	0·24	0·31	0·32	0·32	0·35	0·25	0·21	0·17
Profile IV. Gonhri field, alkaline area								
	Calcium				*Sodium*			
0—6	2·32	3·43	8·22	8·25	6·95	5·78	2·04	1·02
6—12	2·09	3·35	8·74	8·09	6·23	4·91	2·05	0·98
12—20	4·38	6·89	12·03	14·45	13·11	10·04	4·22	0·94
20—27	2·99	6·00	9·49	10·83	8·78	6·49	2·39	1·20
27—32	2·98	3·25	6·02	5·88	3·62	2·41	1·87	1·15
32—39	4·02	4·59	4·93	4·14	2·01	1·45	0·98	1·26
39—53	9·69	10·96	13·25	13·39	2·78	2·04	1·68	1·13
53—60	10·46	11·65	13·21	14·42	2·98	2·10	2·00	1·40
	Magnesium				*Potassium*			
0—6	2·03	1·98	1·54	1·01	0·21	0·18	0·20	0·22
6—12	2·44	2·02	2·00	1·34	0·23	0·22	0·21	0·21
12—20	2·29	2·01	1·56	1·65	0·15	0·16	0·19	0·21
20—27	1·68	1·54	1·52	1·55	0·19	0·20	0·21	0·22
27—32	2·31	2·25	2·01	1·78	0·12	0·11	0·10	0·19
32—39	2·06	1·98	1·88	1·78	0·23	0·19	0·22	0·18
39—53	4·29	3·42	2·87	1·78	0·21	0·21	0·20	0·24
53—60	4·03	3·86	2·45	1·95	0·33	0·41	0·34	0·29

Discussion

There appears to be very little similarity in mechanical composition between the different alkaline patches in the Pentangular area. In the alkaline Profile I, the clay contents decrease irregularly with depth, while in the Profile II, clay increase irregularly with it. It is also observed that the soils in Profile I are more sandy than those of Profile II which have on an average, more clay. A major difference lies in the maximum salt concentration (0·641) in Profile I occurring at the surface and the same (0·622) of the normal profile of the same field, occurring at 56-61 in. depth. The pH value (10·23) is also highest at this depth. It may be noted that the highest pH in Profile I also occur at a similar depth, i.e. 50 in. below. In all probability, the normal area is a portion of the field going to develop into an alkaline patch or an alkaline area undergoing partial reclamation by rains or floods during ordinary irrigation.

There are, however, some similarities in the soils of the different profiles in the Pentangular area. These are in the tendency of the pH to increase and soluble salts to decrease with depth.

The soils of the alkaline Profile IV of a different field Gonhri are of a different nature. The soils are somewhat less sandy and in mechanical composition, resemble the soils of the Profile II of the Pentangular field, though there is no regular tendency of the clay to increase or decrease with depth. Unlike the profiles (alkaline and normal) of the Pentangular field, the pH values (8·13-9·23) decrease with depth and the total soluble salts (0·053—0·286) follow a similar tendency.

The maximum $CaCO_3$ is observed at 39-53 in. in the profile from the Gonhri fields (54·09). The soils from the Pentangular field are also rich in $CaCO_3$ (about 40 per cent) the maximum being 49·3 per cent at a depth of 20-50 in. of the Profile III. In the uncultivated area, the amount of $CaCO_3$ varies from 34·39 to 39·22 per cent. In the cultivated and the orchard plot profiles, the variations are from 22·53 to 33·71 and 35·42 to 47·74 per cent respectively. The minimum $CaCO_3$ content is observed at a depth of 14-28 in. of the cultivated profile, which is extremely sandy (sands 90·12 per cent). On the whole it appears that the soils developing alkalinity may have, on an average, higher contents of $CaCO_3$.

Soluble salts vary from 0·089 (18-55 in.) to 0·279 (0-12 in.) in Profile II, from 0.064 (40-50 in.) to 0·641 (0-6 in.) in Profile I and from 0·064 (20-50 in.) to 0·622 (56-61 in.) in the normal area of the Pentangular field. The same in Gonhri field profile varies from 0·053 (39-53 in.) to 0·286 (0-6 in.). The variations in the salt contents of the uncultivated, cultivated (Dhab) and the orchard plot profiles are respectively from 0·058 to 0·134, from 0·034 to 0·064 and from 0·056 to 0·091 per cent. The alkaline soils are, therefore, somewhat richer in salt content than other soils.

The alkaline patches are characterised by the presence of soluble carbonates. They occur at different depths in different profiles. Soluble carbonates are present at 20-50 in. and 56-61 in. depths in the non-alkaline area profile. At these depths, soluble Ca salts are practically absent. Both alkaline and normal areas in the

Pentangular field are rich in soluble sodium, the greatest concentration (0·206) occurring at a depth of 56-61 in. of the normal area which also contains the highest amount of sodium sulphate. Soluble sodium varies from 0·007 to 0·206 per cent in these soils, while in other soils, the variation is from traces to 0·018 per cent.

Ca forms the predominant exchangeable base in the uncultivated, cultivated and the orchard plot profiles. In the normal and alkaline areas of the Pentangular field, exchangeable Ca is sometimes exceeded by exchangeable Mg (Profile II). Though the degree of sodiumisation is not very high, exchangeable Na occurs in appreciable amounts in the soils of the alkaline patches and is much higher in amounts than that in soils of the other profiles. Exchangeable K shows little variations in these soils.

An overall picture of the Pusa soils of different areas will show that the soils of the patches are mainly saline, alkalinity being only temporary. It will appear that the development of salinity or alkalinity is most probably due to impeded movement of soluble salts in the subsoil. High $CaCO_3$ contents of the soils may be to some extent responsible for generation of soluble salts but where there is free movement of salts as in the case of sandy soils, salts cannot accumulate and develop salinity or alkalinity. Where the movement of salts is restricted due to the occurrence of higher amounts of clay in a dispersed state, salts tend to accumulate and whatever movement, climate or agricultural practices may offer, lead to the sodiumisation of the exchange complex at whatever depths this may occur.

The salinity and alkalinity in Pusa soils are only moderate and most of the former is due to sodium sulphate which is the least harmful of the sodium salts. The real difficulty seems to be the presence of soluble carbonate of sodium. From the composition of some of the soils washed repeatedly with water (Tables V and VI) it may be suggested that reclamation by heavy flooding during winter is expected to be successful.

Summary and Conclusions

Seven soil profiles, both from normal and alkaline areas under different conditions and systems of agricultural practices at Pusa, Bihar were collected and examined during the present investigation. These patches appear during the winter and disappear during the monsoon.

The alkaline patches are observed to be more saline and alkaline than the adjacent portions in the fields where normal crop growth is observed. The patches in different fields are different from each other in the degrees of sodiumisation of the exchange complex, the nature of the sodium salts and in their mechanical composition. The alkaline patches are not characterised by any particular mechanical composition.

Successive leaching with water results in lowering of salinities and in some cases pH values of the soils of the alkaline profiles. The process also brings about desodiumisation of the exchange complex in the soils.

As alkaline patches contain large amounts of soluble salts, an association of salinity and alkalinity together in these soils can be inferred. It is probably fair to assume that alkalinity is caused by movement of soluble salts through the soil, causing replacement of Ca of the soil complex by Na of the salts.

Acknowledgement

Some of the data presented in the article have been taken from a paper read at the 33rd Session of the Indian Science Congress in 1945 and from a thesis submitted by the junior author and accepted by the University of Bombay for the Ph. D. degree in 1948.

REFERENCES

A. O. A. C. (1945). Official and Tentative Methods of Analysis of the Association of Official Agricultural Chemists

Basu, J. K. (1930). Scientific Reports of the I. I. A. R. 1930-31, 53-54

Hissink, D. J. (1923). Method of estimating adsorbed bases in soils and the importance of these bases in soil economy. *Soil Sci.* 15, 269

Howard, A. (1925). The origin of alkali land. *Agric. J. India* ; 461-462

Leather, J. W. (1902). Some excessively saline Indian well waters. *Trans. Chem. Soc.* 81 ; 887-888

Newth, G. S. (1911). A Manual of Chemical Analysis. Longmans Green and Co., London. 260

piper, C. S. (1947). Soil and Plant Analysis, The University of Adelaide, Adelaide. 154-168

Puri, A. N. (1929). A new method of dispersing soils for mechanical analysis. *Mem. Dept. Agric. India Chem.* **10**, 8 ; 209-220

Schollenberger, C. J. and Driselbis, F. R. (1930). Analytical methods in base exchange investigations in soils. *Soil Sci.* **30** ; 161

Sen, J. (1917). Some observations on the occurrence of infertility under trees. *Agric. J. India.* **12** ; 390-405

Tiurin, E. V. (1927). Pedology **22**, 5-24 from Soil Analysis by C. H. Wright. (1934). 201. (Original not seen)

STUDIES ON THE CHARACTERISTICS OF SALINE AND ALKALINE PATCHES IN SOILS OF THE KARNAL FARM

By ABHISWAR SEN, M.Sc., Ph.D., Assoc. I.A.R.I., Indian Agricultural Research Institute, New Delhi

(Received for publication on 4 November, 1952)

AT Karnal, due north of Delhi, the Indian Agricultural Research Institute has a sub-station to represent the soil-climatic conditions of the Punjab. The climate is semi-arid. The soils are formed from Jumna alluvium and are greyish brown in colour. They vary in texture from loam to sandy loam. Saline and alkaline patches in cultivated fields of this area are a common sight. The present article deals with the characteristics of saline and alkaline patches found at the sub-station. These patches are characterised in the extreme cases by the complete absence of variation while normal crops grow in the adjacent portions. The colour of the affected portions is brownish black indicating the presence of free alkali in the soil. *Kans* (*Sachcharum spontanum*) a difficult weed to eradicate, is the only crop sometimes found growing in the affected areas. The overall production of agricultural crops in an area containing many saline and alkaline patches is always very poor.

The Punjab alluvium was found to consist of a shallow soil crust overlying sand. With rising water table, the salts moved towards the surface and formed an accumulation. Though accumulation of salt did not appear to affect the mechanical composition of the soils [Nasir, 1923] lateral movements of the salts were observed to be restricted and rise of salt at any point depended solely on the local charcteristics and on factors causing the rise. Mehta [1937] observed that in large areas of the Punjab, there was invariably a salt bearing layer some distance below the surface. The main salt was sodium sulphate. In monsoon the salts were either stationary or had a downward movement and in winter there was an upward movement and the soil deteriorated. The first stage of the process was associated with the accumulation of soluble salts and the second stage was due to the transformation of a large portion of the normal clay to sodium clay. Taylor and Mehta [1941] recognised that irrigation in this region was followed by an accumulation of salts in the surface layers of the soils. At the same time, soil conditions during the pre-irrigation period had also its influence on the development of salinity and alkalinity in soil. They traced the origin of the sodium sulphate in the Punjab soils to deposition along with the alluvium during a past glacial period.

The salinity or alkalinity of the Karnal soils as detected by qualitative tests, varies at different places but the most affected area are Plot 7 and parts of Plots 5 and 6. Profile samples of soil were taken from these plots by digging pits in them.

Plot 5 (Pit I) showed a large number of alkaline patches : in the portion of Plot 6 (Pit II) where another pit was dug no such patches were seen. Pits III and IV were dug in Plot 7. At Pit III, the soil was completely devoid of any vegetation.

The place where Pit IV was dug had not, so far, been cultivated and was used for grazing purposes only.

The present study was expected to show the differences in the characteristics of soils of normal and alkaline patches of this region and also to reveal how far the observations made on these soils differed or resembled the same made by earlier workers on similar patches elsewhere.

Materials and Methods

Soils

Morphological descriptions of the soils of the profiles taken for examination are given in Table I.

Table I

Morphological description of the soil profiles from Karnal

Depth in inches	Description
	Profile I. Pit I, Plot 5, alkaline
0—7	Grey, structureless, sandy loam
7—24	Dark grey, hard and compact, granular, pea-shaped dark coloured nodules increase with depth
24—40	Dark grey but of lighter colour than above, clay loam less compact than above, granular, mixed with dark pea-shaped nodules
40—59	Grey, slightly sticky, loam, calcareous concretions appear below 45 inches; no pea-shaped nodules
59—below	Same as above, calcareous concretions in abundance, strong effervescence with dilute HCl
	Profile II. Pit II, Plot 6, normal
0—5	Grey, sandy loam, grass roots present
5—38	Dark grey, clay loam, hard and compact, the hardness increasing with depth, breaking into lumps, occurrence of insect bores
38—55	Yellowish grey, loam, hard and compact, dark pea-shaped nodules present
55—71	Yellow, sandy, loose, falling to powder easily on pressing between fingers, no effervescence with HCl at any depth of the pit

TABLE I—(*contd.*)

Morphological description of the soil profiles from Karnal

Depth in inches	Description
	Profile III. Pit III, Plot 7, saline
0— 5	Grey, sandy, loose, structureless, white salt incrustations at the top,, mixed occasionally with calcareous nodules of varying sizes
5—25	Grey with yellowish tinge, loam, occasionally with calcareous nodules of varying sizes
25—48	Yellowish grey, loam, breaking up into powder easily, slightly sticky downwards, abundance of blackish nodules
48—below	Almost a bed of large sized calcareous nodules, mixed with yellowish grey soil, strong effervescence with HCl
	Profile IV. Pit IV, Plot 7, uncultivated area
0—21	Grey loam, grass roots present, small pieces of bricks appear near about 9 inches
21—40	Dark grey, loam, compact and hard but friable below 42 inches, few roots present
40—47	throughout, effervescence with dilute HCl

Methods

The mechanical analysis of the soils were carried out by NaCl dispersion [Puri, 1929]. CO_2 contents of the soils were determined by Schrotter's method [Newth, 1911] ; these were converted to $CaCO_3$. The *p*H values of the soils were determined by the Glass Electrode.

The soils were washed with 40 per cent alcohol [Piper, 1947] before leaching with normal neutral ammonium acetate solution for the determination of base exchange capacity and exchangeable Mg, K and Na [Schollenberger and Dreiselbis, 1930]. Exchangeable Ca was determined by Hissink's method [Hissink, 1923] as modified by Tiurin [1927].

Analysis of the water extracts was carried out by the usual methods [A.O.A.C., 1945]. For combination of soluble acids and bases into salts Leather's procedure [Leather, 1902] was followed.

RESULTS

The mechanical composition, *p*H values and $CaCO_3$ contents of the soils of the Karnal profiles are given in Table II.

TABLE II

Mechanical composition, pH and $CaCO_3$ contents of the soils of the Karnal profiles (expressed as per cent on moisture-free basis)

Depth in inches	Mechanical fractions				pH	$CaCO_3$
	Coarse sand (2·0—0·2 mm.)	Fine sand (0·2—0·02 mm.)	Silt (0·02—0·002 mm.)	Clay (<0·002 mm.)		
Profile I. alkaline						
0— 7	34·23	31·03	26·34	8·40	9·91	1·14
7—28	20·51	28·74	22·72	28·03	10·36	1·06
28—42	20·77	24·80	26·57	27·86	10·46	0·32
42—59	12·04	37·75	23·81	26·40	10·28	0·90
59—below	67·33	12·35	12·81	7·51	10·22	46·38
Profile II. normal						
0— 5	37·96	21·99	25·55	14·50	7·77	0·06
5—38	28·77	20·28	23·92	27·03	7·56	0·17
38—55	32·04	21·87	19·53	26·56	7·73	0·04
55—71	50·87	15·15	17·19	17·12	8·01	0·10
Profile III. saline						
0— 5	39·65	30·68	23·58	6·09	10·34	4·05
5—25	32·80	29·53	18·55	19·12	10·46	1·48
25—48	24·04	36·34	18·98	20·64	10·39	2·28
48—below	43·49	17·17	25·51	13·83	10·40	34·18
Profile IV. uncultivated						
0—21	42·67	12·90	26·20	18·23	7·96	0·78
21—40	31·45	18·98	24·29	25·28	7·96	0·18
40—47	26·29	16·94	27·97	28·80	8·48	0·31

It can be observed that the soils of the normal uncultivated profiles have more clay at the surface than those of the saline and alkaline profiles. The latter are also characterised by a zone of accumulation of $CaCO_3$ below 59 inches in the alkaline and below 48 inches in the saline profiles while the normal and uncultivated profiles have no such layer.

The salt contents, soluble acids and bases and probable amounts of Na_2CO_3 Na_2SO_4 and NaCl are given in Table III.

Table III

Saline constituents of the soils of the Karnal profiles

(expressed as per cent on moisture-free basis)

Depth in inches	Total soluble salts	NO_3	CO_3	HCO_3	Cl	SO_4	Ca	Mg	K	Na
				Profile I. alkaline						
0—7	0·263	0·020	0·015 (Na_2CO_3 -0·013)	0·021 ($NaHCO_3$ 0·030)	0·039 (NaCl -0·064)	0·080 (Na_2SO_4 -0·118)	0·004	0·002	0·005	0·077
7—28	0·189	0·004	0·012	0·031 ($NaHCO_3$ -0·054)	0·018 (NaCl -0·029)	0·048 (Na_2SO_4 -0·070)	0·006	0·002	0·005	0·065
28—42	0·119	0·002	0·012 (Na_2CO_3 -0·004)	·028 ($NaHCO_3$ -0·038)	0·011 (NaCl -0·018)	0·026 (Na_2SO_4 -0·038)	0·004	0·002	0·002	0·031
42—59	0·144	0·001	0·021	0·012	0·021 (NaCl -0·035)	0·042 (Na_2SO_4 -0·058)	0·004	0·009	0·002	0·033
59—below	0·111	..	·021 (Na_2CO_3 ·013)	..	0·025 (NaCl -0·041)	0·023 (Na_2SO_4 -0·035)	0·002	0·004	0·003	0·033
				Profile II. normal						
0—5	0·095	0·008	..	0·028	0·039 (NaCl -0·029)	0·015	0·006	0·006	0·004	0·012
5—38	0·093	0·001	..	0·024	0·018 (NaCl -0·015)	0·023	0·009	0·008	0·008	0·003
38—55	0·084	..	..	0·015	0·018 (NaCl -0·029)	0·028 (Na_2SO_4 0·005)	0·003	0·006	0·004	0·013
55—71	0·075	..	..	0·031	0·018 (NaCl -0·003)	0·006	0·011	0·004	0·002	0·004

TABLE III—(*contd.*)

Saline constituents of the soils of the Karnal profiles

(*expressed as per cent on moisture-free basis*)

Depth in inches	Total soluble salts	NO_3	CO_3	HCO_3	Cl	SO_4	Ca	Mg	K	Na
				Profile III. saline						
0—5	0·674	0·028	0·156 (Na_2CO_3 -0·276)	..	0·089 (NaCl -0·146)	0·143 (Na_2SO_4 -0·212)	0·001	0·002	0·008	0·247
5—25	0·094	..	0·034 (Na_2CO_3 -0·030)	..	0·011 (NaCl -0·018)	0·014 (Na_2SO_4 -0·020)	0·002	0·005	0·003	0·026
25—48	0·071	..	0·024	0·012 ($NaHCO_3$ -0·016)	0·011 (NaCl -0·018)	0·002 (Na_2SO_4 -0·002)	0·002	0·009	tr	0·012
48—below	0·049	..	0·012 (Na_2CO_3 -0·005)	..	0·005 (NaCl -0·009)	0·012 (Na_2SO_4 -0·018)	0·003	tr	0·005	0·011
				Profile IV. uncultivated						
0—21	0·054	tr	0·002	0·018	0·012	0·005	0·007	0·005	0·002	tr
21—40	0·151	..	0·003	0·012	0·018 (NaCl -0·029)	0·071 (Na_2SO_4 -0·072)	0·004	0·006	0·002	0·035
40—47	0·171	..	0·002	0·031	0·021 (NaCl -0·035)	0·064 (Na_2SO_4 -0·086)	0·005	0·004	0·002	0·042

The base exchange capacity and the exchangeable bases in the soils are given in Table IV.

TABLE IV

Base exchange capacity and the exchangeable bases in the soils of the Karnal profiles

(*expressed as milli-equivalents per cent on moisture-free basis*)

Depth in inches	Total base exchange capacity	Exchangeable bases			
		Ca	Mg	K	Na
		Profile I, alkaline			
0—7	6·15	0·80	0·59	0·39	6·00
7—28	17·15	tr	0·42	0·26	13·74
28—42	17·05	tr	0·88	0·27	19·08
42—59	15·60	tr	0·28	0·49	15·33
59—below	4·75	tr	0·88	0·09	5·29

TABLE IV—(*contd.*)

Base exchange capacity and the exchangeable bases in the soils of the Karnal profiles

(*expressed as milli-equivalents per cent on moisture-free basis*)

Depth in inches	Total base exchange capacity	Exchangeable bases			
		Ca	Mg	K	Na
		Profile II. normal			
0—5	10·75	5·80	0·05	0·25	1·12
5—38	14·60	8·05	1·10	0·05	3·69
38—55	15·90	11·20	1·13	0·20	4·49
55—71	11·78	9·95	0·31	0·11	2·29
		Profile III. saline			
0—5	7·40	tr	0·82	0·36	8·45
5—25	11·30	tr	0·41	0·24	12·76
25—48	12·23	0·40	1·50	0·38	10·44
48—below	8·40	tr	3·60	0·57	5·53
		Profile IV. uncultivated			
0—21	12·65	8·50	2·16	0·64	4·76
21—40	15·73	8·80	1·67	0·36	2·14
40—47	18·13	6·75	3·13	0·82	12·86

DISCUSSION OF RESULTS

From the data in Table II, it will appear that the mechanical composition of the soils of all the profiles is somewhat similar. The clay contents increase up to a certain depth after which they decrease. In the case of saline and alkaline profiles, the surface soils are more sandy than the corresponding soils of the normal and uncultivated profiles. These observations do not agree with the findings of Nasir [*loc. cit.*], who showed that the soils of the alkaline patches did not differ much from those in adjacent normal areas. In the case of the soils of the alkaline profile, clay increases with depth up to 59 inches after which it decreases. In the saline profile, this decrease after a more clayey overlying layer is noted at 48 inches and below. At these depths, $CaCO_3$ nodules are observed. The zone of accumulation of $CaCO_3$ is, therefore, at a lower depth in the alkaline profile than in the saline profile.

Deterioration of the soils of the Punjab is believed to be chiefly due to the formation of a zone of accumulation of soluble salts with the introduction of irrigation [Taylor and Mehta, *loc.* cit.]. It is doubtful if such a zone of accumulation of soluble salts exists in the soils studied. Maximum salt concentration occurs at the surface in the normal (0·095), saline (0·634) and the alkaline (0·263) profiles. In the case of the uncultivated profile, however, maximum salinity (0·171) is observed at 40—47 in. depth. The occurrence of maximum salt concentration at the lowest depth of the uncultivated profile can hardly be attributed to be due to a zone of accumulation of salts as the salt content at this depth is not very high as compared to the maximum salt concentrations in the soils of the other profiles.

Alkali carbonates are present in the soils of the saline and alkaline profiles. In the case of the former, the amounts are higher than in the case of the alkaline soils. From the probable composition of the sodium salts present in these soils (Table III) contents of sodium sulphate vary from 0·0 to 0·005 per cent in the normal from 0·0 to 0·086 per cent in the uncultivated, from 0·002 to 0·212 per cent in the saline and from 0·035 to 0·118 per cent in the case of the soils of the alkaline profile. Contents of sodium chloride vary from 0·003 to 0·029, from 0·0 to 0·035, from 0·009 to 0·146 and from 0·018 to 0·064 per cent respectively in the normal, uncultivated, saline and alkaline profiles. The predominance of sodium sulphate in the alkaline alluvium of the Punjab has also been observed by other workers [Taylor and Mehta, Mehta, *loc. cit.*]. It has been found from the data in Table III that there exists a positively significant correlation between ' SO4 ' and ' Cl ' ($r = 0{\cdot}8912$), between 'CO_3' and 'SO_4' ($r = 0{\cdot}6867$) and between 'CO_3' and 'Cl' ($r = 0{\cdot}8912$). The relationship between the acid radicals can be expressed by the following two equations :

(i) $CO_3 = -0{\cdot}0051 + 0{\cdot}7087\ SO_4$

(ii) $CO_3 = -0{\cdot}0129 + 1{\cdot}6666\ Cl$

*p*H values of the soils of the normal profile vary from 7·56 to 8·01, in the uncultivated from 7·96 to 8·48, in the saline from 10·34 to 10·46 and in the alkaline from 9·91 to 10·46. There is, therefore, very little difference between the soils of the saline and alkaline profiles as such and also between different layers of the two profiles. Puri, Taylor and Ashghar [1937], have described a typical profile in the alkaline alluvium of the Punjab to be having three well marked layers : an upper highly alkaline layer, a layer with $CaCO_3$ nodules of medium alkalinity and a layer with lower alkalinity. In the profiles studied, however, there is very little difference in alkalinity at different depths of the saline and alkaline profiles. The reaction does not show any marked decrease even at the depths where $CaCO_3$ nodules are observed in profusion.

The soils of the different profiles show varying degrees of sodiumisation. Exchangeable sodium constitutes from 15·51 to 28·63 per cent of the exchangeable bases in the normal profile, from 16·49 to 54·59 per cent in the uncultivated, from 57·01 to 95·16 per cent in the saline and from 77·12 to 95·22 per cent of the exchangeable bases in the alkaline profile. The exchangeable Ca comprises from 62·45 to

80·33 per cent of the total exchangeable bases in the normal profile, from 20·65 to 67·85 per cent in the uncultivated from traces to 3·14 per cent in the saline and from traces to 10·28 per cent in the alkaline profile.

The low $CaCO_3$ contents of the soils of the normal and uncultivated profiles may indicate greater leaching of Ca in these soils than those of saline and alkaline profiles where the process must have been more restricted in the past. Absence of any layer of accumulation of $CaCO_3$ probably shows that precipitation of Ca salts by alkaline subsoil water [Puri, 1937] has not occurred within the depths studied.

The precipitation of the leached Ca salts has occurred at different depths in the alkaline and the saline patches. In the alkaline profile it occurs at 59 inches and below while in the saline profile it is below 48 inches as evidenced by the contents of $CaCO_3$ at these depths.

Apart from the distinction made in the case of the alkaline and saline patches from visual characteristics (black colour in the case of the alkaline soil and whitish salt incrustation in the case of saline one, both without common vegetation), there is really no difference between them. The formation of lime concretions at different depths in such soils has been explained by Gillam [1931]. At these depths, the soils of both the profiles are much more sandy than the layers immediately above. For precipitation of Ca from a solution of its salts in a soil, a porous layer appeared to be necessary [Ramann, 1911]. A characteristic feature of these depths is the absence of bicarbonates.

Higher salinity and alkalinity of the soils of the uncultivated area, over those of the normal profile will suggest the possibility of the former's gradual development into a saline and ultimately into an alkaline patch. A similar tendency was observed in the case of soils in Sind by Tamhane [1920] according to whom, leaving the land fallow and absolutely out of cultivation under such conditions, favoured the formation of alkaline patches.

Summary and Conclusions

Four soil profiles, from normal, uncultivated, saline and alkaline areas were collected from the agricultural sub-station, Karnal and examined for physico-chemical characteristics.

It has been observed that the soils of the normal profile have the lowest salt content, pH and the content of exchangeable Na. In the uncultivated profile, the soils are more saline and they show a greater degree of sodiumisation. pH values and the degrees of sodiumisation are highest in the saline and alkaline soils. Maximum salt concentration occurs at the surface of the normal, saline and alkaline areas, while it occurs at the lowest depth of the uncultivated profile. There is very little difference between the soils of the saline and alkaline profiiles ; the pH values do not vary very much from depth in these soils.

The surface soils of the saline and alkaline profiles are more sandy than those in the normal and the uncultivated profiles. The former are characterised by a zone of accumulation of $CaCO_3$ in the form of nodules ; this zone in the case of other

4 AR/53

soils is absent. Saline and alkaline soils are richer in $CaCO_3$ than the soils of the normal and uncultivated areas at other depths also.

ACKNOWLEDGEMENT

The data presented in this article have been taken from a thesis submitted by the author and accepted for the Ph. D. degree by the University of Bombay in 1948. The author's grateful thanks are due to Dr S. V. Desai and Dr S. P. Raychaudhuri for kind help and many valuable suggestions.

REFERENCES

A. O. A. C. (1945). Official and Tentative Methods of Analysis of the Association of Official Agricultural Chemists

Gillam, W. S. (1937). The formation of lime concretions in the Moody and Crofton series. *Proc. Soil Sci. Soc. Amer.* **2** : 471-477

Hissink, D. J. (1923). Method of estimating absorbed bases in soils and the importance of these bases in soil economy. *Soil Sci.* **15** ; 269

Leather, J. W. (1902). Some excessively saline Indian well waters. *Trans. Chem. Soc. 81* ; 887-888

Mehta, M. L. (1937). Soils of the rice areas of the Guzranwala and Sheikupura Divisions of the Upper Chenab Canal. *Punjab Irrig. Res. Inst. Publ.* **3**, (2)

Nasir, S. M. (1923). Some observations on the barren soils of Lower Bari Doab Colony in the Punjab. *Agri. Res. Inst. Pusa, Bull.* **145**

Newth, G. S. (1911). A manual of Chemical Analysis. Longmans Green & Co., London. 260

Piper, C. S. (1947). Soil and Plant Analysis. The University of Adelaide, Adelaide. 159

Puri, A. N. (1929). A new method of dispersing soils for mechanical analysis. *Mem. Dept. Agri. Indian Chem. Ser.* **10**, 209-220

Puri, A. N. (1937). Report of the Punjab Irrigation Research Institute for the year 1938

Puri, A. N., Taylor, E. M. and Ashghar, A. G. (1937). Soil deterioration in the canal irrigated areas of the Punjab. III. Formation and characteristics of soil profiles in the alkaline alluvium of the Punjab. *Punjab Irrig. Res. Inst. Publ.* **4**, 9

Ramann, E. (1911). Bodenkunde Ed. III Julius Springer, Berlin

Schollenberger, C. J. and Dreiselbis, F. R. (1930). Analytical methods in base exchange investigations in soils. *Soil Sci.* **30**, 161

Stewart, G. R. (1918). Effect of season and crop growth in modifying soil extract. *J. Agri. Res.* **12**, 311-368

Tamhane, V. A. (1920). Comparison of salt lands in the Deccan and Sind. *Agric. J. India,* **15**, 410-417

Taylor, E. M. and Mehta, M. L. (1941). Some irrigation problems in the Punjab. *India J. Agric. Sci.,* **11** 137-169

Tiurin, E. V. (1927). Pedology *22*, 5-24 from Soil Analysis by C. H. Wright (1934). 201 (Original not seen)

STUDIES ON THE SALINE SOILS OF THE DELHI STATE

II. SOME TYPICAL PROFILES OF THE JUMNA *KHADAR* AREA (SOUTH)

By S. P. Raychaudhuri and R. D. Tripathi, Indian Agricultural Research Institute, New Delhi

(Received for publication on 7 February 1953)

As discussed in Part I of this study [Raychaudhuri and Sankaram, 1952], the Delhi State has been divided into four natural physiographic divisions: namely (i) *Khadar* (new alluvium), (ii) *Bhangar*, (iii) *Dabar* and (iv) *Kohi*. Principal geological formations in the State are (i) alluvia which is of recent origin and (ii) Delhi system. As a preliminary to the detailed soil survey, which has not been done previously, reconnaissance survey of the soil in the *khadar* area of the Delhi State was undertaken. In part I of this series studies of the profile and other soil characteristics in the northern part of the *khadar* area have been reported. The present communication deals with the same type of investigation in the southern area. Location of the site is the eastern side of the village Madanpur *khadar*; right side of the Agra Canal. It is a low lying basin-shaped area. This southern part is often flooded and water-logged in rainy season. The general water table is very high and comes close to the ground level during the rains, and internal drainage of the tract is very poor. As precipitation is below evaporation, leaching of the soils remains incomplete.

After broad reconnaissance survey of the area salinity and water-logging appeared to be the main problems which were limiting factors in crop yield. Attention was, therefore, paid to the study of the saline and non-saline soils representative of the tract. This study which is mainly from the point of view of reclamation will, also, serve as a pre-irrigation soil study for the area which is proposed to be irrigated in the near future by sewage effluent and will also throw light on the nature of the soils of this area.

Preliminary examination of a number of profiles was made and two profiles were selected in sites representative of the area from the point of view of salinity and other morphological conditions. One was in the cultivated area which had high salt concentration and efflorescence at the top and this represented the average condition of the salinity found in the whole of the tract. One surface-sample upto a depth of three inches was also taken in its vicinity, where the efflorescence appeared to be the highest and there was no crop growth. This area was under wheat. The site for the second profile was at a slightly higher level than the first one and in a grazing area. The profiles were dug till a permanent sand layer was reached

4 AR/53

[28 in. – 40 in.]. Morphological descriptions of the profiles along with their physical and chemical characteristics are given below.

DESCRIPTION OF THE PROFILES

Profile I

Date of collection 9 February 1950

Location, etc. Eastern side of village Madanpur *Khadar*, about three miles away from Okhla. Right side of Agra Canal and about 200 yd. away from the Canal road.

Landscape. Low lying, basin-shaped area with poor drainage.

Alkali. Surface whitened with efflorescence.

Natural vegetation. Grasses, namely

(i) *Cynadon dactylon*

(ii) *Alhagi camelorum*

Condition. Cultivated area under wheat.

TABLE I

Depthwise description of Profile I

Depth in inches	Description
0— 7	Grey, silty loam, structureless, few roots present, no concretion, moderate effervescence with dilute HCl
7—10	Grey, silty loam, structureless, thin roots present, slow effervescence with dilute HCl
10—11	Greyish white, sand, single grain, no roots, no effervescence with dilute HCl
11—13	Greyish white, loamy sand, single grain, no roots and no effervescence with dilute HCl
13—19	Greyish white, sand, single grain, no roots, and no effervescence with dilute HCl
19—21	Grey, sandy loam, structureless, no roots and no effervescence with dilute HCl
21—40	Greyish white, sand, single grain, no roots and no effervescence with dilute HCl

The soils are often flooded by river water during the rainy season.

Profile II

Date of collection 9 February 1950

Location, etc. Right side of Agra Canal, ½ mile away from the canal road on the eastern side of the village Madanpur *Khadar.*

Landscape. Plain, at a slightly higher level than the Profile I.

Drainage. Intermediate, alkali (white efflorescence) not visible.

Natural vegetation. Small grasses, mostly *Indigofera linifolia.*

Condition. Grazing ground.

TABLE II

Depthwise description of Profile II

Depth in inches	Description
0—11	Grey, silty loam, undeveloped structure, roots present, slight effervescence with dilute HCl, few black spots, moist
11—16	Slightly yellowish grey, silty loam, structureless, roots present, more brownish spots than above, more moist, moderate effervescence with dilute HCl
16—17	Greenish grey, loamy sand, single grain, roots present, no effervescence with dilute HCl, less moist than above
17—19	Slightly yellowish grey, silty loam, structureless, roots present, moist as second horizon, slight effervescence with dilute HCl
19—23	Greenish grey, sand, single grain, roots absent, moist as third layer above, no effervescence with dilute HCl
23—28	Pinkish or slightly violet coloured, sand, rest as the fifth layer above

Methods of analysis

The methods of analysis are the same as given in first part of the paper.

RESULTS

Data on physical and physico-chemical properties of the samples analysed are given in Tables III to VIII.

TABLE III

Mechanical analysis

(per cent on oven dry basis)

Depth in inches	Coarse sand	Fine sand	Silt	Clay	Carbonate $CaCO_3$	pH of the soil
			Profile I			
0—7	1·0	46·5	34·8	11·6	3·1	8·1
7—10	0·2	64·8	23·6	8·3	2·5	7·8
10—11	1·3	89·7	4·0	3·7	2·1	7·2
11—13	0·6	73·6	15·4	6·1	2·1	7·7
13—19	11·5	82·6	3·3	3·4	1·1	7·2
19—21	0·5	78·0	12·3	5·6	2·0	7·6
21—40	0·5	91·3	3·7	1·9	0·8	7·3
Surface	0·3	46·9	32·2	13·4	2·8	8·1

TABLE III—(*contd.*)

Mechanical analysis

(*per cent on oven dry basis*)

Depth in inches	Coarse sand	Fine sand	Silt	Clay	Carbonate $CaCO_3$	pH of the soil
			Profile II			
0—11	0·8	59·0	26·1	9·8	3·4	7·9
11—16	0·2	48·4	34·3	11·7	3·6	8·1
16—17	2·3	82·4	8·5	4·1	1·9	7·8
17—19	0·2	41·1	40·5	12·8	3·9	7·9
19—23	10·6	84·7	1·7	2·0	1·1	6·8
23—28	25·1	72·5	1·9	1·9	0·7	6·8

TABLE IV

Water soluble salts

(*per cent on oven dry basis*)

Depth in inches	CO_3	HCO_3	Cl	SO_4	Ca	Mg	K	Na	Total salts (Sum of cations+anions)
					Profile I				
0—7	..	0·037	0·150	0·073	0·014	0·007	0·012	0·097	0·390
7—10	..	0·037	0·010	0·041	0·016	0·001	0·014	0·013	0·131
10—11	..	0·031	0·017	0·032	0·015	0·006	0·009	0·016	0·126
11—13	0·006	0·031	0·028	0·037	0·011	0·008	0·018	0·023	0·162
13—19	..	0·018	0·048	0·037	0·005	0·006	0·017	0·027	0·158
19—21	0·006	0·031	0·028	0·026	0·011	0·006	0·014	0·015	0·136
21—40	..	0·024	0·007	0·043	0·007	0·008	0·015	0·003	0·107
Surface 0—3	0·018	0·037	0·324	0·260	0·009	0·007	0·012	0·235	0·901
					Profile II				
0—11	..	0·043	0·049	0·032	0·014	0·003	0·016	0·026	0·182
11—16	0·006	0·043	0·021	0·018	0·013	0·006	0·011	0·014	0·131
16—17	0·006	0·046	0·009	0·017	0·015	0·006	0·006	0·005	0·109
17—19	0·006	0·043	0·010	0·028	0·016	0·006	0·012	0·008	0·129
19—23	..	0·024	0·014	0·022	0·018	0·004	0·009	0·002	0·087
23—28	..	0·024	0·007	0·014	0·006	0·002	0·019	0·001	0·074

TABLE V

Base exchange capacity and exchangeable bases

(*per cent on oven dry basis*)

Depth in inches	Exchangeable cation (milli-equivalents)			Total exchange capacity (milli-equivalents	Sodium saturation per cent	Dispersion co-efficient
	Ca+Mg	K	Na			
			Profile I			
0—7	1·90	1·91	1·48	5·29	28	45·1
7—10	3·70	1·00	1·00	5·70	17	21·8
10—11	..	1·90	1·91	3·03	50	N. D.*
11—13	1·94	1·40	0·64	3·98	16	10·4
13—19	0·83	0·94	0·43	2·20	22	N. D.*
19—21	1·63	0·94	1·51	4·08	37	5·0
21—40	0·64	0·99	0·62	2·26	27	N. D.*
Surface 0—3	2·59	..	2·57	5·15	51·80	44·3
			Profile II			
0—11	3·45	0·27	1·08	5·79	18	24·9
11—16	6·69	1·17	0·96	8·82	10	18·8
16—17	1·37	1·91	1·01	4·28	23	N. D.*
17—19	7·73	0·70	1·63	10·05	16	21·6
19—23	0·27	0·71	0·95	1·9	49	N. D.*
23—28	1·55	0·21	0·04	2·8	1	N. D.*

*N. D.—Not determined

TABLE VI

Chemical analysis

(*per cent on oven dry basis*)

Depth in inches	C	N	HCl soluble P_2O_5	HCl soluble K_2O	C/N ratio
			Profile I		
0—7	0·40	0·06	0·118	0·509	6·9
7—10	0·25	0·04	0·119	0·576	6·9
10—11	0·10	0·02	0·095	0·420	4·1
11—13	0·20	0·03	0·110	0·501	6·3
13—19	0·09	0·01	0·084	0·377	5·5
19—21	0·18	0·03	0·118	0·426	6·8
21—40	0·03	0·01	0·105	0·452	2·5

TABLE VI—(*contd.*)

Chemical analysis

(*per cent on oven dry basis*)

Depth in inches	C	N	HCl soluble P_2O_5	HCl soluble K_2O	C/N ratio
			Profile II		
0—11	0·35	0·07	0·118	0·599	5·0
11—16	0·38	0·05	0·112	0·615	8·0
16—17	0·17	0·03	0·081	0·524	4·9
17—19	0·44	0·06	0·119	0·279	6·8
19—23	0·06	0·01	0·076	0·303	5·6
23—28	0·04	0·01	0·181	0·190	4·0

TABLE VII

Single value physical constants

(*on oven dry basis*)

Depth in inches	Moisture equivalent	Index of texture	Clay per cent	Clay+Silt per cent
		Profile I		
0— 7	22·31	13·25	11·6	46·3
7—10	15·82	14·46	8·3	32·0
10—11	6·32	N. D.*	3·7	7·7
11—13	12·50	11·33	6·1	21·5
13—19	5·00	11·44	3·4	6·7
19—21	9·35	11·44	5·6	17·9
21—40	5·54	13·36	1·9	5·6
0— 3 (Surface)	22·23	13·18	13·4	45·7
		Profile II		
0—11	15·62	11·60	9·8	35·9
11—16	22·23	19·76	11·7	46·0
16—17	9·69	11·96	4·1	12·6
17—19	25·79	21·34	12·8	53·4
19—23	4·57	7·7	2·0	3·7
23—28	5·05	N. D.*	1·9	3·8

*N.D.—Not determined.

TABLE VIII

Analysis of clay fraction

Depth in inches	SiO_2 per cent	Al_2O_3 per cent	Fe_2O_3 per cent	Molar SiO_2/R_2O_3	Molar SiO_2/Al_2O_3	Molar Al_2O_3/Fe_2O_3	Total exchange capacity (m.e./100 gm. oven dry basis)
				Profile II			
0—11	54·33	29·30	13·03	2·45	3·15	3·52	22·45
11—16	54·03	31·11	14·06	2·29	2·95	3·46	27·81
16—17	55·89	32·34	12·26	2·36	2·94	4·13	24·70
17—19	53·26	28·14	13·36	2·47	3·22	3·30	20·69

DISCUSSION

Mechanical analysis

The results show that upto 10 inches in the profile I and upto 16 inches in the profile II, the soils are silty loam in texture. Later on, loamy sand and sandy layers appear generally in the profile which meet the pure sand layer at the bottom. In the profile II, a heavy layer of silty loam texture appeared in the profile after a sandy layer, showing the possibility of mechanical eluviation of silt and clay particles. The percentage of silt has been found to be generally 2-4 times the percentage of clay.

In a saturated soil, the percolation rate is determined by the permeability of the least pervious horizon. This horizon in this case is silty loam in texture and the internal drainage of the soil appears to be good.

Carbonate. Except in the bottom sandy layer of profile II, content of calcium carbonate in all the horizons is about 2 to 3 per cent.

Water soluble salts. In both the profiles the highest concentration of water soluble salts decreased down the profiles. This shows that the salinization is taking place mainly from the top, and internal drainage is impeded due to the water table being too high. The total concentration of soluble salts in the surface layer has been found to be approximately as high as one per cent. The limit is generally considered to be unfavourable for the plant growth [Kellogg, 1937].

The anions of soluble salts consist mainly of chlorides and sulphates, bicarbonates are also present, but content of carbonate is rather low and in many horizons absent. Amongst the soluble cations, sodium has been found to be far greater in amount than calcium in the top horizons of both the profiles and also in the surface samples. Proximate composition of soluble salts shows [Leather, 1902] that sodium is present

generally in the form of chloride and sulphate, the carbonates and bicarbonates being mainly of divalent cations. But appearance of $KHCO_3$ in the surface sample (0-3 in.) has shown the possibility of the appearance of the carbonates of potassium and sodium in due course of time.

*p*H. Soils are generally nearly neutral to slightly alkaline in all the horizons except in the surface one which are more alkaline than the lower horizons.

Exchangeable bases and total exchange capacity. The exchange complex is fully saturated with bases, and that sodium has gained considerable entry into it. All the horizons of the profile I, which has got higher soluble salt concentration, as well as higher sodium percentage, are more sodium saturated than those of the second profile. *p*H of the soil seems to vary according to the absolute amount of exchangeable sodium, rather than by percentage sodium saturation.

Base exchange capacity of the soils are generally low. As is expected, total exchange capacity of soils in horizons varies directly with percentage of clay, exceptions being in the horizons with high percentage of soluble salts, which showed comparatively low exchange capacity [*Nature and diagnosis,* California, 1947].

Nutrient status of the soil. The data show that in the first profile, where the soluble salt content is too high, C/N ratio is highest on the top and decreases downwards. In the second profile C/N ratio increases upto second horizon (11 in. – 16 in. and then decreases.

HCl soluble P_2O_5 is generally constant in all the horizons in the profiles. K_2O decreases with depth. The soils are poor in organic matter. The nitrogen content of the top layer is fair. The soils are well supplied with P_2O_5 and K_2O.

Clay analysis. The data show that the percentage of SiO_2, Al_2O_3 and Fe_2O_3, as well as, the molar SiO_2/Al_2O_3 and SiO_2/R_2O_3 ratio are all nearly uniform throughout the profile indicating the absence of eluviation or illuviation of any of these constituents. Very little variation in the total exchange capacity of clay is suggestive of the same fact.

Mineralogical analysis

The analysis of fine sand fraction from Profile II shows that the soils contain high amount of muscovite, biotite, and hornblende (above 30 per cent). Chlorites, ziosite and garnet are also found in enough quantity (10-30 per cent). In the profile II in the sixth horizon, garnet was visible even to the naked eye.

Nature and development of these soils. The soils are developed under semi-arid climate, where the influence of micro-relief and ground-water are dominant. The soils receive washings and accumulations of soluble salts from the neighbouring areas where these are of general occurrence due to climatic effects [Jenny, 1941]. As pointed out previously the soil is saline containing generally 0·9 per cent of soluble salts in the surface. The water soluble salts are highest at the top and decrease downwards showing that salinisation is taking place mainly from the top. This also shows that the soils have impeded drainage. The ground-water table which generally comes very close to the surface in rains and remains high throughout the year, also contributes its quota of soluble salts to some extent. In fact, analysis shows that it contains 105 parts of total solids per 100,000 parts.

Amongst the soluble cations the sodium exceeds calcium on the top and the calcium sodium ratio ranges from 1 : 6 (0-7 in.) to 1 : 27 (0-3 in.) in the profile I. Calcium forms 12 per cent and 3 per cent of the total water soluble cations in the above two horizons respectively. The concentrations are enough to cause entrance of sodium in exchange complex upto the extent of 28 per cent (0-7 in.) and 51 per cent (0-3 in.) in the surface soil.

But this entry has not caused much increase in *p*H and the highest *p*H recorded is only 8·1. This is due to high soluble salt Concentration. The general absence of Na_2CO_3 also points out the same fact.

Classification

The soil is a structureless saline alkali soils [*Nature and diagnosis* California, 1947]. The soil cannot be called a Solonetz, which possesses a compact structure in the B-horizon [MacGregar, *et al.*, 1945] and low soluble salt concentration [Joffe, 1949]. It cannot be called a Black-alkali [Hilgard, 1906] because of the absence of sodium carbonate. It cannot also be distinguished as salty alkali soil [Sigmond, 1938] because of the absence of sodium carbonate and presence of abundance of calcium carbonate throughout the profile.

The position of these soils in the world group can be shown as follows [Thorp and Smith, 1949].

Order	Sub-Order	Great soil group
Intrazonal	Halomorphic	Saline-alkali

The great soil group has been designated as saline alkali, since it cannot be placed either in the Solonchak group due to high percentage of sodium in the exchange complex or in the Solonetz group due to absence of sodium carbonate and non-existence of the compact structure.

Its zonal component seems to be the grey soil of semi-arid region for the reasons given below [Joffe, 1949] :

(*a*) Gray colour, semi-arid climate and xerophytic vegetation.

(*b*) Low content of organic matter.

(*c*) Alkaline reaction.

(*d*) Low base exchange capacity and complete saturation of the exchange complex.

(*e*) Not much difference in the chemical composition of different horizons as shown by SiO_2/Al_2O_3 and SiO_2/R_2O_3 ratio.

Summary

Reconnaissance soil survey of the southern zone of the *khadar* area of the Delhi State was undertaken. Saline and alkaline soils are prevalent in this tract which

4 AR/53

are responsible for large portion of this land being unproductive. Detailed studies were made of the characteristic feautres of soils and profiles of the region from the point of view of reclamation. The soils in general are sandy to loamy in texture. Water soluble salts are very high and gradually decrease with depth and sodium is present in greater amount than calcium. The soils are base saturated though the base exchange capcaity is low and sodium has gained considerable entry into the exchange complex. The soils contain high amount of muscovite, biotite and hornblende. Chlorites, ziosite and garnet are also present in fair amount.

ACKNOWLEDGEMENT

Thanks are due to Mr. N. Sen for the mineralogical analysis of the sand fractions and Mr. H. B. Singh for identification of the natural vegetation.

REFERENCES

Raychaudhuri, S. P. and Sankaran, A. (1952). *Indian J. agric. Sci.* **22**, 209

Basu, J. K. and Tagare, V. D. (1943). *Indian J. agric. Sci.* **13**, 157

Hilgard (1906). *Soils*

Jenny, H. (1941). *Factors of soil Formation, N. J.*

Joffe, J. S. (1949). *Pedology, N. J.*

Kelley, W. P. (1934). *J. agric. Sci.,* **24**, 77

Kelley, W. P. and Arany, A. (1928). *Calif. Expt. Sta. Hilgardia.* **31**, 393

Kellog, C. E. (1937). *U. S. D. A. Misc. Pub.* 274

Leather, J. W. (1902). *Trans. Chem. Soc.* **81**, 887

Lyons, T. L. and Buckmann, H. G. (1947). *Nature and properties of soils,* 314

MacGregor, J. M. and Wyatt, F. A. (1945). *Soil Sci.* **59**, 419

Mackenzie Taylor and Mehta, M. L. (1941). *Indian J. agric. Sci.* 11, 137

Sigmond, A. A. J. (1932). *Imp. Bur. Soil Sci., Tech. Con.* 23

Sigmond, A. A. J. (1938). *Principles of soils science,* 255—280

Thorp, J. and Smith, R. (1949). *Soil Sci.* **67**, 117

Thorp, J. and Smith, R. (1947). Diagnosis and improvement of saline and alkaline soils. *U.S. D. A. Bur. Plant. Indus, Soils and Agri. California*

A STUDY OF THE ACTION OF TANK SILT ON SOIL

By Abhiswar Sen and G. L. Asija, Indian Agricultural Research Institute, New Delhi

(Received for publication on 8 May 1953)

TANK silts and silts of various origin are known to possess considerable manurial value and are used by cultivators to restore fertility of soils [Mukherjee, 1923]. The observations made on the beneficial effects from application of tank silts to soils seem to be supported by results of experiments, done in our country by Tamhane [1935], Sayer (1935), and more recently by Ram and Pai [1951].

The exact nature of the action of such silts on soils is, however, not very well known. It would appear, from considerations of soil economy, that the annual loss of finer particles through run-off should be replenished to restore original conditions in the soils and the easiest way to achieve it was probably to apply tank or river silts to the soils under cultivation wherefrom such losses were usually heavy. Taylor [1935] believed that the application of silts to soils resulted in marked improvement in the physical conditions of the soils. This view appears to have been supported by the results of experiments of Sayer and Tamhane [*loc.cit.*]. But applications of tank silts are usually not so heavy as to alter to any remarkable extent, the mechanical composition of the soils. They are also not expected to consist only of silt and clay but to contain a good amount of organic matter by their getting mixed up, in course of time, with refuses of marine flora and fauna inhabiting the tanks. Under anaerobic conditions at the bottom of tanks, losses of nitrogen from the decomposition of organic matter are expected to be minimum and it is, therefore, quite likely that the tank silts should be rich in plant foods as well. The composition of silts examined by Hoon and Dhawan [1944] in the Punjab were not very rich in manurial constituents ; those obtained from different parts of West Bengal showed that some of the silts were quite rich in nitrogen and other plant foods [Sen and Das, 1951]. It was, however, not known if this nitrogen could easily nitrify in soils to make itself available for crops, as organic matter in lake deposits are known to be highly resistant to decomposition [Allgeier, Peterson, Juday and Birge, 1932].

The object of the present investigation was to study nitrification of some of the silts from West Bengal, in soil. As no Bengal soil was available in quantity, Delhi soil was used for the purpose. It was hoped that the results would also reveal if any loss of nitrogen occurred when tank silts were mixed with this particular soil with high *p*H as quite an appreciable portion of nitrogen contained in the tank silts was in the form of ammonia. Along with the determinations of nitrate, nitrite, organic and ammoniacal nitrogen, those of organic carbon, *p*H and soluble salt contents of the silt treated soils were carried out with a view to ascertain the changes associated with nitrification of tank silts.

Materials and methods

Soil and the silts

The sample of Delhi soil, selected for the experiments had a pH 8·1. The soil was collected from a depth of one foot and when air dry, sampled through a two mm. sieve before mixing with the silts which were also sampled in a similar way. The composition of the soil is given below :

Composition of Delhi soil

(constituents expressed as per cent on oven dry basis)

pH	8·1
Org. C	0·308
Org. N	0·045
NH_4- N	0·0014
NO_2- N	*Nil*
NO_3- N	Traces
Coarse sand	1·58
Fine sand	71·69
Silt	14·21
Clay	10·92
P_2O_5	0·07
K_2O	0·54
CaO	1·42
Soluble salts	0·112

The tank silts were collected from the bottom of tanks dried up during summer from the following villages in West Bengal.

1. Aurangabad (Murshidabad)
2. Kalyanpur (24-Parganas)
3. Khirapai (Midnapur)
4. Maldah (Maldah)
5. Noada (Murshidabad)
6. Rajnagar (Midnapur)
7. Suri (Birbhum)

The tank silts were obtained, for the purpose of the experiments, through the courtesy of the Director of Agriculture, West Bengal.

The composition of the silts is given in Table I.

TABLE I

Composition of the tank silts

(constituents expressed as per cent on oven dry basis)

Constituents	Aurangabad	Kalyanpur	Khirapai	Maldah	Noada	Rajnagar	Suri
*p*H	7·20	6·60	5·48	5·19	7·58	4·81	6·58
Org. C	2·69	1·56	1·00	2·61	2·41	2·84	2·86
Org. N	0·249	0·166	0·102	0·194	0·260	0·218	0·282
NH_4- N	0 016	0·019	0·018	0·030	0·019	0·019	0·018
Coarse sand	20·11	9·67	46·08	9·66	14·73	16·36	10·97
Fine sand	43·51	17·38	18·83	36·66	37·39	23·25	37·95
Silt	..	47·31	18·91	36·33	29·99	32·40	30·43
Clay	36·38	25·64	16·18	23·33	17·89	27·99	20·65
P_2O_5	0·37	0·21	0·15	0·19	0·13	0·12	0·28
K_2O	0·85	1·00	0·37	0·71	1·13	0·76	0·97
CaO	1·29	1·12	0·31	0·23	3·07	0·53	2·19

Methods

The silts were mixed in such proportions with the soil as to add about 30 mg. of nitrogen to 100 gm. of it. As they varied in composition, the quantities of silt mixed with each 100 gm. lot were different for different silts and the final composition of the soil silt mixtures were different. The mechanical composition of the soil silt mixtures is given in Table II. Before the nitrification experiments were started, the saturation capacities of the mixtures were determined and the moisture contents of the soil silt mixtures were maintained at one-third their saturation capacities throughout the period of the experiment [Walton 1928 ; Biswas, Singh and Joshi, 1946]. Losses of moisture were made up at the time of each observation. Nitrate,

TABLE II

Mechanical composition of the soil silt mixtures

(constituents expressed as per cent on oven dry basis)

Constituents	Delhi soil mixed with silt from						
	Aurangabad	Kalyanpur	Khirapai	Maldah	Noada	Rajnagar	Suri
Coarse sand	3·47	2·71	10·48	2·53	2·85	3·23	2·43
Fine sand	68·83	64·11	61·04	67·55	68·37	66·24	68·63
Silt	12·77	18·82	15·15	16·83	15·74	16·26	15·69
Clay	13·51	12·98	11·98	12·38	11·59	12·84	11·81

4 AR/53

nitrite, organic and ammoniacal nitrogen, organic carbon, pH and salt contents of the soil silt mixtures were determined at the beginning of the experiment and at intervals of two weeks. The nitrification experiments with each silt were carried out in duplicates. They were discontinued after ten weeks.

Twenty-five grams of the mixtures were shaken with 125 c.c. of distilled water. Twenty-five c.c. of the suspension were used for colorimetric estimation of pH [Report of the Sub-Committee, Soil Science Committee, I. C. A. R., 1951]. The original suspension was shaken for two hours and filtered. Fifty c.c. were evaporated to dryness for the estimation of soluble salts and 20 c.c. were used for the estimation of nitrates. Five c.c. were used for the estimation of nitrites. For the estimation of the latter, two c.c. of 0·5 per cent solution of sulphanilic acid in 30 per cent acetic acid and one c.c. of a similar solution of a-naphthylamine were added to the clear extract. The colour developed was matched against known standards [Wright, 1934].

Twenty grams of the mixtures were shaken and leached with N NaCl solution till the leachate measured one litre. This was distilled with NaOH for the estimation of ammonia. The soil residue was washed with a few c.c. of distilled water and then used for the estimation of organic nitrogen.

Five grams of the mixtures were used for the estimation of organic carbon. The determinations were carried out by the usual methods [A. O. A. C., 1945].

Results

In Table III are given the average contents of organic, ammoniacal nitrite and nitrate nitrogen of the soil silt mixtures during different periods.

Table III

Nitrogen contents of the soil silt mixtures at different periods (in mg. per cent on oven dry basis)

Type of nitrogen	Original	2 weeks	4 weeks	6 weeks	8 weeks	10 weeks
			Aurangabad			
Org. N	63·10	70·68	68·14	71·78	71·69	70·92
NH_4- N	7·00	12·00	11·29	6·29	10·68	17·68
NO_2- N	0·14	0·03	0·02	0·03	0·03	0·08
NO_3- N	·84	2·38	4·61	6·18	7·63	8·14
Total	71·08	85·09	84·06	84·28	90·03	96·82
			Kalyanpur			
Org. N	66·40	60·46	62·88	62·24	71·20	71·17
NH_4- N	19·39	20·70	8·70	7·09	18·32	18·67
NO_2- N	0·70	0·03	0·02	0·03	0·04	0·03
NO_3- N	·82	3·09	4·52	6·19	8·48	8·89
Total	87·32	84·28	76·12	75·55	98·04	98·76

TABLE III—(*contd.*)

Nitrogen contents of the soil silt mixtures at different periods.

Type of nitrogen	Original	2 weeks	4 weeks	6 weeks	8 weeks	10 weeks
			Khirapai			
Org. N	60·00	51·29	53·57	66·27	65·48	64·89
NH_4- N	8·50	11·70	11·91	8·68	7·10	21·24
NO_2- N	0·09	0·04	0·02	0·03	0·03	0·03
NO_3- N	0·48	2·35	5·10	6·76	8·30	8·55
TOTAL	69·07	65·38	70·60	81·74	80·91	94·71
			Maldah			
Org. N	77·70	63·68	67·23	69·61	69·63	71·12
NH_4- N	11·00	13·40	7·33	5·33	11·73	13·35
NO_2- N	0·09	0·04	0·02	0·03	0·04	0·04
NO_3- N	·45	2·37	5·82	7·61	7·85	9·00
TOTAL	89·24	79·49	80·40	82·58	89·35	93·51
			Noada			
Org. N	66·00	63·02	58·80	67·22	71·76	73·50
NH_4- N	10·20	12·80	15·09	13·96	9·41	9·27
NO_2- N	0·15	0·03	0·01	0·03	0·02	0·04
NO_3- N	0·59	2·29	5·11	7·10	8·68	8·61
TOTAL	76·94	78·14	79·01	88·31	89·87	91·42
			Rajnagar			
Org. N	70·00	67·11	67·99	68·41	71·85	73·91
NH_4- N	10·20	14·21	9·66	3·98	9·42	25·02
NO_2- N	0·11	0·04	0·02	0·01	0·04	0·04
NO_3- N	0·56	2·18	4·89	6·25	8·41	9·22
TOTAL	80·87	83·54	82·56	78·65	89·72	108·19
			Suri			
Org. N	73·00	65·26	59·74	68·41	67·08	73·08
NH_4- N	11·00	13·60	8·02	2·39	9·36	12·31
NO_2- N	0·18	0·03	0·03	0·03	0·04	0·03
NO_3- N	·64	3·09	5·73	6·56	8·08	9·07
TOTAL	84·82	81·98	73·52	77·39	84·56	94·49

The data given in Table III establishes, beyond doubt, the easy nitrifiability of tank silts. Delhi soil, used in the experiment, formed only 3·0 mg. of nitrate nitrogen under the same conditions during a period of ten weeks.

Average contents of organic carbon, soluble salts and *p*H values of the soil silt mixtures during the periods under observation are given in Table IV.

TABLE IV

Contents of organic carbon and soluble salts (mg. per cent) and the pH values of the soil silt mixtures at different periods during nitrification

Contents and *p*H	Original	2 weeks	4 weeks	6 weeks	8 weeks	10 weeks
			Aurangabad			
Organic carbon	411·5	394·7	251·5	352·0	316·6	323·4
Soluble salts	128·0	226·9	276·5	296·3	258·1	210·0
*p*H	8·0	7·9	7·9	7·9	7·9	7·9
			Kalyanpur			
Organic carbon	464·7	398·1	329·7	342·2	308·9	341·2
Soluble salts	145·0	137·7	169·5	209·3	233·0	233·3
*p*H	7·8	7·6	7·6	7·8	7·9	7·9
			Khirapai			
Organic carbon	393·8	301·8	222·6	313·0	397·1	282·6
Soluble salts	125·0	178·9	239·0	225·3	188·1	188·6
*p*H	7·9	8·0	8·0	7·9	7·9	7·9
			Maldah			
Organic carbon	400·8	307·7	342·0	319·9	272·4	295·7
Soluble salts	150·0	226·0	256·1	282·6	261·7	254·0
*p*H	7·9	8·0	8·0	7·8	7·9	7·8
			Noada			
Organic carbon	433·1	409·5	295·3	403·3	335·9	336·7
Soluble salts	130·0	271·7	316·6	326·1	193·8	200·1
*p*H	7·8	7·9	7·8	7·9	7·9	7·9
			Rajnagar			
Organic carbon	447·2	317·8	253·3	398·7	336·3	326·0
Soluble salts	140·0	303·8	345·8	340·9	329·8	223·5
*p*H	7·8	7·9	8·0	7·9	7·9	7·9
			Suri			
Organic carbon	451·9	385·9	252·4	348·9	311·5	324·0
Soluble salts	135·0	149·7	210·8	220·5	285·2	274·8
*p*H	7·8	7·4	7·6	8·0	7·9	7·9

Discussion of results

From the data presented in Table III, it is seen that quite a good amount of nitrogen was present in the soil silt mixtures in the form of ammonia at all the stages studied. Though the amounts of ammoniacal nitrogen at different stages showed considerable variations nitrates increased continuously in all the cases. Nitrites remained in traces all throughout. It appears, therefore, that while the rate of nitrification was more or less uniform and it progressed with progress of time, the rate of ammonification, though persistent, was somewhat irregular.

As tank silts are known to contain quite a significant portion of its nitrogen in the form of ammonia, it was suspected that at least some nitrogen would be lost by volatilisation when applied to an alkaline soil [Subrahmanyan, 1937]. From the total nitrogen content of the soil silt mixtures, it could be seen that except in the case of silts from Aurangabad and Noada, losses of nitrogen had occurred in all the other soil silt mixtures for some weeks, after which there was not only recovery but actual increase in the contents of total nitrogen. From the trend of values of ammoniacal and nitrate nitrogen, particularly between 4th and 8th weeks, a certain amount of denitrification was also observed. In the case of silts from Aurangabad and Noada, fixation of nitrogen started from the beginning and the increases in nitrogen were maintained throughout. The amounts of fixed nitrogen were appreciably high in all the cases at the end of ten weeks and this fact alone might account for the continued fertility of silt treated soils.

Reaction of tank silts seemed to influence the loss of nitrogen from soil silt mixtures during nitrification. In silts from Aurangabad and Noada, having pH values above 7·0, there was never any loss of nitrogen. Silts having pH values less than 7·0 were found liable to lose nitrogen in the initial stages following application to soils.

The processes of nitrification and fixation of nitrogen by Azotobacter are both associated with loss of carbon. The progressive nitrification and fixation of nitrogen observed in all the cases could hardly be justified by the observed values of organic carbon at different periods (Table IV). It may be fair to assume that growth and multiplication of nitrogen fixing blue green algae were responsible for the observed fixation of nitrogen. Loss of carbon due to nitrification and fixation of nitrogen by Azotobacter if any must have had been made up at least to a certain extent by carbon of the algae. The presence of the latter had already been reported by Prasad and Patabardhan [1941].

The increase in the salinity of the soil silt mixtures (Table IV) were due to many factors and known among them are the formation of nitrates and to some extent, the solvent action on soil of carbon dioxide produced during nitrification. In a soil like Delhi, which already contained a fair amount of soluble salts, the salt content increased appreciably at certain stages, but at later periods showed a decrease. It would appear probable that application of tank silts to a saline soil might increase its salinity for the first few weeks but the increased salinity might not be permanent. The nitrates formed would be required for the nutrition of crops and also of the soil microbiological population.

The present report deals with the action of tank silt on a sandy and an alkaline soil from Delhi. Experiments on their effect on an acid soil from Assam and a non-acid clayey soil from Madras are in progress. It is also proposed to study the microbiological population during different stages of nitrification in the soil silt mixtures.

Summary and conclusions

Tank silts from seven different villages in West Bengal were mixed with a sandy and alkaline soil from Delhi so as to add about 30 mg. of nitrogen to each 100 gm. of the latter. Moisture contents of the soil silt mixtures were maintained at one third their saturation capacities. Organic, ammoniacal, nitrite and nitrate nitrogen contents of the mixtures were determined along with their *p*H values, soluble salt contents and contents of organic carbon at intervals of two weeks.

It was observed that the tank silts contained easily nitrifiable nitrogen. Amounts of nitrates in the soil silt mixtures increased more or less uniformly throughout the period of the experiment.

Silts having *p*H values less than 7·0, showed some loss of nitrogen in the initial stages of nitrification. In silts with *p*H values higher than 7·0, no such loss was noticed at any stage. Where losses of nitrogen occurred, they were made up after some time. Appreciable fixations of nitrogen were, however, observed in all the soil silt mixtures at the end of ten weeks.

As a result of nitrification of the silts in Delhi soil, there was an increase in the content of soluble salts. The salt content decreased at later stages. As a portion of the increased soluble salts had been due to nitrates, this increase in the salinity of the soil was not expected to be permanent.

References

A. O. A. C. (1945). Official and Tentative Methods of Analysis of the Association of Official Agricultural Chemists

Allgeier, R. J., Peterson W. H., Juday C. and Birge. E. A. (1932). The anaerobic decomposition of lake deposits. A *Symposium on Hydrobiology* (1941). *The University of Wisconsin Press*, 100 (original not seen)

Biswas, S. C., Singh H. D. and Joshi N. V. (1946). Comparative studies on Indian soils, VIII The comparative nitrifying capacity of soils. *Indian J. agric. Sci.*, 16, 413

Hoon, R. C., and Dhawan B. C. (1944). A study of the fertilising value of the silts carried on suspension by the rivers of the Punjab. *Indian J. agric. Sci.*, 14, 69-74

Mukherjee, N. G. (1923). *Hand Book of Indian Agriculture.* Thacker Spink, Calcutta

Prasad M. and Patabardhan N. K. (1941). Studies on physico-chemical changes in black cotton soil during nitrification. *Indian J. agric. Sci.*, 11, 978-992

Ram, C. S. V. and Pai K. V. S. (1951). Fertilisation value of tank silts. *Proc. Indian Acad. Sci.*, B 34 ; 109-113

Report of the Sub-Committee, Soil Science Committee, I. C. A. R. (1951). *Standardisation of methods of soil analysis*, 9

Sayer, W. (1935). The effects of river silts on sugarcane land. *Proc. 1st Meeting of the Soils and Crops Wing of the Board of Agriculture and Animal Husbandry in India*, 272

Sen, A. and Das B. (1951). Composition of tank silts from West Bengal. *Sci. and Cult.*, 17, 93-94

——————— (1951). Tank silt as manure for light soils. *Indian Fmg.*, N. S. 1 : 26

Subrahmanyan, V. (1937). Volatilisation of ammonia from Indian soils. *Curr. Sci.*, B. 587-589

——————— (1937). Estimation of ammonia volatilised from soils. *Nature*, 139, 884

Tamhane, V. A. (1935). The effect of river silts on soils. *Proc. 1st Meeting of the Soils and Crops Wing of the Board of Agriculture and Animal Husbandry in India*, 269

Taylor, M. (1935). Referred to in V. A. Tamhane's note

Walton, J. H. (1928). Nitrification of cyananude. *Mem. Dept. Agri. Ind., Bact. Ser.*, 2, 3, 63

Wright, C.H.(1934). *Soil Analysis.* Thomas Murby & Co., London, 219

EFFECT OF FLOWERING ON THE VEGETATIVE GROWTH AND YIELDS IN THE POTATO VARIETY *PHULWA* (PATNA WHITE)

By A. K. MITRA, Economic Botanist to the Government of Uttar Pradesh and G. C. BOSE, Botanical Assistant

(Received for publication on 10 July, 1950)*

THE *Phulwa* (also called Patna White) is the most common potato variety grown in the plains of Uttar Pradesh and Bihar where it forms the main crop with a duration of about five months. Its tubers are round, medium sized with moderately deep eyes and yellow flesh. As the name indicates this variety flowers profusely. So far as the authors are aware, no work has been done in this country on the effect, if any, of the flowering habit on the growth and tuber yields in the potato crop. The results of whatever little work has been done in other countries also do not agree.

For example, as summarised by Bartholdi [1942], the investigations of Wollney showed increased yields of tubers through removal of flowers while those of Snell, slightly reduced tuber yields in profusely blooming types and slightly higher yields in poorly blooming types. In his own investigations with four varieties representing different degrees of vegetative vigour and flowering and fruiting habits, Bartholdi found that both flowering and fruiting caused significant reductions in vegetative growth and tuber yields.

Again Wilson and Sleesman [1946] came to the conclusion that there was little or no correlation between bloom and yield. In his experiments, the D.D.T. treated plots not only showed the heaviest flower production but also produced the most tubers, while in plots where copper containing formulae were used, the bloom was depressed and yet tuber yields were increased.

In view of this very uncertain position, it was considered highly desirable to find out whether the profusely flowering habit of our very widespread and common plains' variety, the *Phulwa*, had any effects on tuber yields.

With this objective in view, a properly laid out field experiment was conducted at the Government Research Farm, Kanpur, through three successive seasons (i.e. 1944-45 to 1946-47) with all the four combinations of following treatments :

(1) Two sizes of seed : $\frac{1}{2}''$ and $\frac{3}{4}''$ in diameter (1944-45 and 1945-46) and $\frac{3}{4}''$ and $1''$ in diameter (1946-47).

(2) Two flowering treatments, i.e. Allowed to flower and Not allowed to flower.

In the 'Not allowed to flower' treatment, the flower bud clusters were nipped off as soon as they were formed while in the 'Allowed to flower' treatment, the flowering and fruiting was allowed to take their natural course undisturbed.

The design was 'Randomised blocks' with six replications and with four treatment plots per block. The treatment plots each were of about 1/70 acre.

---

* Revised in December, 1952.

4 AR/53

The summarised yields per acre for the different treatments during the three years of this experimet, along with the S.E. and C.D. at the 5 per cent level, are shown in Table I.

TABLE I

Summarised yields per acre in maunds

Season of experiment	Small seed : ½″ Diameter		Larger seed : ¾″ Diameter		Analysis at 5 per cent	
	Allowed to flower	Not allowed to flower	Allowed to flower	Not allowed to flower	S.E.	C.D.
1944-45	115·92	106·32	177·55	164·95	3·64	10·97
1945-46	219·40	218·10	255·50	248·20	8·9	26·82
	Small seed : ¾″ Diameter		Large seed : 1″ Diameter			
1946-47	88·70	77·06	111·16	108·21	5·18	15·61

For facilitating discussion, the results of the main factors, i.e. (1) 'Allowed to flower' *versus* 'Not allowed to flower' and (2) 'Small seed' *versus* 'Larger seed' for the three years of the experiment are also presented in Table II.

TABLE II

Results of main factors

Year	Allowed to flower	Not allowed to flower	½″ seed	¾″ seed	C.D.
1944-45	146·74	135·64	111·12	171·25	7·76
1945-46	237·45	233·15	218·75	251·85	18·97
			(¾″ seed)	(1″ seed)	
1946-47	99·93	92·64	82·88	109·69	11·04

It will be seen from the yield data presented in Table I that there are no significant differences between the 'Allowed to flower' and 'Not allowed to flower' treatments during the two seasons 1945-46 and 1946-47. During the season 1944-45, however, the treatment 'Allowed to flower' with the larger seed size (¾″ in diameter) has come out as significantly superior to the 'Not allowed to flower' treatment. With the small size seed (½″ in diameter) during the same season (1944-45), the 'Allowed to flower' treatment is again very near the significant mark. In fact the pooled results for the main treatments 'Allowed to flower' and 'Not allowed to flower' presented in Table II above, reveal a significant difference in that year, in favour of the 'Allowed to flower' treatment.

It will also be clear from the above tables that in all the seasons, the larger seed has consistently given significantly superior yields as compared to those from small seed. This factor of seed size in relation to yields will, however, form the subject of a separate note.

So far as the flowering treatments are concerned it is interesting to note that the average yields obtained in each of the years and with both sizes of potato seed for the 'Not allowed to flower' treatment is throughout slightly lower than those obtained from the 'Allowed to flower' treatment. It is very likely that this is due partly to the constant disturbance caused in the 'Not allowed to flower' plots by the workers engaged in nipping the floral buds and partly to the shock from nipping injury.

As regards vegetative growth, no noticeable differences were observed in the two flowering treatments.

These results are thus quite contrary to the findings of Bartholdi and conclusively show that the stress of flowering and fruiting in our widely grown and profusely flowering *Phulwa* variety of the plains of North India, has no adverse effects on its vegetative growth or tuber yielding capacity.

Summary

(1) Findings of workers on the effect of flowering and fruiting on the growth and yields of the potato are widely divergent.

(2) The above effects are studied for the profusely flowering variety *Phulwa*, which is the predominant potato of the North Indian plains.

(3) The results in all the seasons consistently revealed that the profusely flowering habit of *Phulwa* potato has no adverse effects whatsoever on tuber yields.

(4) Larger seed was throughout significantly superior yielder than smaller seed.

REFERENCES

Bartholdi, W. L. (1942). Influence of flowering and fruiting upon vegetative growth and tuber yield in the Potato. *Univ. Minn. agric Expt. Sta. Tech. Bull.* 150

Wilson, J. D. and Sleesman, J. P. (1946). Spray materials and the blooming of Potatoes. *Amer. Potato* J. 23

REVIEWS

FORMULATION AND ECONOMIC APPRAISAL OF DEVELOPMENT PROJECTS

BOOKS I AND II

(*Published by the United Nations*)

THESE books reproduce the lectures delivered by the economists and technical experts from different countries and international agencies at the 'Asian Centre on Agricultural and Allied Projects' which was organised jointly by a number of U. N. agencies—FAO, International Bank for Reconstruction and Development, ECAFE, etc.—during the last quarter of 1950. The aim of the Centre was to train candidates from the participating countries in the scientific methods of formulation and appraisal of development projects and presentation of the project schemes in a manner which would facilitate their examination by national and international financing agencies. The manner in which projects are prepared and organised is no doubt an important factor in determining their success. Preparation of sound and scientific projects involves careful consideration and integration into one whole of several different aspects, e.g. engineering and physical aspects, availability of real resources, possible financial arrangements including foreign exchange requirments, possible administrative set-up for its implementation, relation of project to the national economy and national development and comparison of prospective costs and prospective benefits, including direct and indirect benefits, both overall for the life of the project and step by step by time periods of the development. In Book I are discussed the general principles and methods touching these various aspects, types of problems likely to arise and the various alternative ways in which these may be solved. It consists of six parts, each relating to a separate aspect and dealt with by a different expert from some international agency or U. S. Government. The last part throws useful hints about the manner of presentation of development schemes. Book II deals with the formulation of projects of particular type like multipurpose river valley projects, irrigation projects, flood control projects, fertiliser projects, land settlement schemes, fisheries and forestry development projects, etc. with special reference to the advantages likely to accrue from these projects, types of data required for their presentation and analysis of cost-benefit ratio. It also discusses some of the special problems of development, such as organization of agricultural extension services, health problems involved in development projects and democracy and human factor in planning, with special reference in many cases to the conditions in the ECAFE region, and also contains a Chapter on technical assistance available to undeveloped countries and the manner in which it may be obtained. The lectures have a wide range, though some of the points discussed might appear to be of elementary nature to persons who have made a prior study of economics. If Book I deals with the subjects mostly in a theoretical manner, Book II provides many practical examples. The two Books supplement each other. The presentation of the material is simple and mostly in a form which would

4AR/53.

be easily understood even by those who have no advanced knowledge of economics. In fact the publishers have made no attempt to present the lectures in the form of a closely written text-book or professional articles, but have rather left them in the form of colloquial discussions. These Books, containing as they do, lectures by experts who had practical experience of the problems of development and some of whom were actually engaged in examining development schemes submitted by the national Governments to international agencies for assistance, should prove useful to administrators and students dealing with the formulation and appraisal of development projects, and help in focussing their attention on some of the problems which might otherwise tend to be overlooked. The United Nations have done a commendable piece of work in publishing these lectures. (S.R.S.)

THE MOLECULAR ARCHITECTURE OF PLANT CELL WALLS

By R. D. PRESTON

(*Published by Chapman & Hall Ltd., London*)

THE increasing knowledge of the structure of the living material by the application of physical and physico-chemical methods needed a place for record and the present book can claim to have brought together most of the information that is scattered in various publications.

The first five chapters are meant to acquaint both the students of biological and fundamental sciences with the techniques that are employed in the plant cell studies while Chapters VI—X deal with the structure and growth of cells. Lucid presentation of the subject in this book considerably reduces the strain on the reader. Introduction of the polarising-microscope, X-Ray techniques and electron-microscope into the biological fields considerably increased our knowledge of the structure of the cell walls. The data accumulated so far, though valuable, seem to be too meagre to draw generalised conclusions although avenues of promising interest seem to be opening up. The complications that arise in the interpretation of the wall structure starting from the vesicle of an alga, *Valonia*, up to the mature parenchyma cells and the cells of coleoptiles have been discussed.

There are several cautious and ambiguous statements recorded in the book which perhaps reflect on the *preliminary nature* of the data available. For example, it is stated on page 191 that 'it is therfore possible in this particular case that some stages of growth do involve the tensile properties of the wall and it seems likely that the same is true of the majority of other growing cells' while on page 195 it is stated that 'indeed though a final decision must await more precise data obtained in such a way as to be more readily interpreted in terms of growth, it seems at the moment difficult to avoid the conclusion that the tensile properties of the wall have very little indeed to do with the regulation of the growth'.

A book of this type is very welcome and on the whole is, no doubt, a useful addition to the botanical literature. (C.D.)

LAND REFORMS

By Karuna Mukherjee

(*Published by S. Chatterjee & Co., Calcutta, Price Rs. 5*)

THIS book is divided into eleven chapters. The first six chapters covering 72 pages give useful background information in a summary form. Then follow the two really important chapters of the book. These deal with the existing legislation on the subject of zamindari abolition and the pattern of agrarian reorganization in the post-zamindari abolition period. Next follows, chapter IX, a summary of agrarian reforms in foreign countries based largely on a U. N. O. publication, 'Land Reforms'. The last two chapters deal with the problems of crop sharers, under-tenants and agricultural labourers.

Zamindari abolition legislation, which is being implemented in most parts of India today, represents the culmination of efforts in this direction extending over several years. It is doubtless a great step forward in as-much-as it seeks to remove all intermediaries between the tenant (legal occupant) and the State and thus creates conditions conducive to efficient agriculture. It might also mean some improvement in the revenues of the State even after providing for payment of compensation through bonds. But zamindari abolition legislation which has hitherto been enacted, should not be considered as the last step in the sphere of agrarian reforms. It is in fact like the clearing of decks for further actions. Several important problems have yet to be tackled. These include the problems of share-croppers, under-tenants and landless labourers. The author touches on some of the important problems connected with the agrarian structures of India and Pakistan and offers some suggestions. But one looks in vain for any deep analysis of the problems posed. Some of the factual data used are also not the latest available. For instance, on page 16 the author gives data in respect of land holding from the Famine Commission's Report even though later data are available in the report of U. P. Zamindari Abolition Committee (*vide* p. 174).

On the whole, however, the book gives in a useful form a summary of existing information on the subject and the author has done well to bring out the need for further agrarian reforms. (M.S.).

FARM MECHANISATION DIRECTORY, 1953

(*Published by Temple Press, London, 1952*)

THE Directory is compiled by the staff of 'Farm Mechanization' and is a guide for importers, dealers, distributors and farmers, who are interested in purchasing farm machiner yfor their particular needs. The guide confines its pages to farm tractors, machines and equipment of British manufacture. The importance of this guide to Commonwealth countries may be gauged by the statement, that 'a major part of the out-put of farm machinery, which is approximately about £100 million per year from the United Kingdom alone, is destined for overseas markets'.

The Directory is divided into four parts. Part I, consists of a list of organisations in the U. K., interested in farm mechanisation. These include manufacturers' associations, professional bodies, government departments and research institutes. A small note on their activities is also given. Continuation of this Part is an index of names and addresses of all manufacturers of agricultural machinery, tractors and allied equipment, which is alphabetically arranged.

Part II starts with a classified list of British built tractors, which gives a gist of manufacturers' specifications for each model of tractor. Some specifications of American tractors built in the U. K. are also included here. Separate groupings have been made of track layers, half tracks, wheel tractors of over 10 H.P., and also walking type tractors. Copies of tractor test reports, issued by the National Institute of Agricultural Engineering in the U. K. are also included. These test reports cover most of the British tractors now under production and a few from continental make particularly from Germany and Italy. The usefulness of this part would be more for Commonwealth countries, in case a test report for all European tractors could be added, based on the test procedure and form adopted by the N.I.A.E. It is stated, in the Directory that ' these tests aim at providing information, which is reasonably comparable with the results of universally accepted tests on other countries'. Although, it is not clearly mentioned, evidently it means, that these British test reports are for reasonable comparison with the Nebraska tests of the U.S.A. The position seems to be at present, that British tractors have to compete in world markets (and in India too) with Canadian and American tractors, which are invariably covered by the Nebraska tests. It would be in the interest of British tractor manufacturers, to adopt a comparable test method with that of Nebraska or this Directory should indicate a method of comparison between the British and American form of test reports. A time may come when the consuming countries may insist on any one form to which they are used to or on a universally accepted method, as mentioned herein. They may even evolve a new method for making a strict comparison between tractors reports from various countries of the world. It may interest one to know that India imports tractors from nine different countries of the world each of which has its own method of testing.

Part III is a classified list of agricultural implements machines, vehicles and accessories and some small workshop equipment. This part is quite comprehensive and includes pumps, poultry equipment and such other agricultural accessories.

Part IV is a classification of machines and equipment, which will be useful as a guide for commercial purposes, import control authorities and customs officials who have to distinguish between agricultural and non-agricultural equipment for purpose of assessing customs duty.

The Directory is fully illustrated, with firms' advertisements here and there. The quality of paper used and printing are very good. As mentioned earlier, the Directory is useful for importers and dealers of agricultural equipment. As it refers only to British production, it is necessary to mention here that there are comparable publications of the same nature from the U.S.A., dealing with tractors and power implements.

While the publication is a statement of facts of the British products, the buyers want to know, what other alternative goods are available from competing countries. As this Directory is useful in Commonwealth and other countries of the world where British goods have to compete with others, it is suggested that test-report forms are made of a 'universally accepted' type so that the buyer may compare and judge one product with another. (R.V.R.)

THE ANTIQUITY OF SOME FIELD AND FOREST FLORA OF INDIA

By A. K. YEGNA NARAYAN AIYER

(Published by A. K. Yegna Narayan Aiyer, Bangalore, Price Rs. 2 or 4 shillings)

THE practice of agriculture and fruit growing has been known in India from the pre-historic times. The different crops that were grown in the early days are mostly recorded in Sanskrit literature and therefore they are not widely known. Many scholars of Sanskrit and ancient Indian history tell us that our savants of the past had a remarkable knowledge of the plants which were either cultivated or were used for the benefit of man. Most of these plants, their uses and their probable botanical equivalents are listed in the present book, written in English, by a veteran agricultural scientist. About 300 of such plants have been listed in alphabetical order with some very valuable notes against each of them. The literature from which these plants have been recorded appeared during a period from 1500 to 3000 years ago.

A perusal of this book, brings to our mind a general picture of the crops that flourished in the fields and the fruits that enriched the orchards of ancient India. In those days, we believe, our fields were fertile and contrary to the present day position, our country was not so short of food. Some of the ethnobotanical references about these crops and their varied uses and nomenclature, undoubtedly indicate their antiquity. Such references are often helpful in solving the difficult task of deciding the original home of some of these crop plants. For example, sugarcane, rice, sesamum, black pepper and mustard are now known to have originated in India and this view is partly borne out by the numerous references about these plants in ancient Indian literature.

In his introductory remarks to the book, the author has stated that for various reasons, he had to use the older botanical names instead of the modern names. Unfortunately, however, he has accepted some very old and in some cases quite obsolete names which are often not traceable. This would somewhat tend to reduce the value of the book as correlation of the Sanskrit names with accepted botanical names becomes difficult. For example, *Amomum anthorrihon* (page 18) and *Chironia sapida* (page 40) could not be traced in botanical literature except in Colebrooke's edition of *Umura kosha* [Calcutta, 1807]. Both these names were used by Colebrooke from Roxburgh's manuscripts of either *Hortus Bengalensis* [1814] or *Flora Indica* [1832] but these names, having not been finally published in these books must be regarded as invalid. Colebrooke [*l.c.* page 94] has suggested a species of *Grewia* as the alternative plant for *Priyala* or *Chironjia sapida* which is an acceptable name,

but somehow *Grewia* has not been cited by the author. The silk-cotton tree (page 16) and the *Salmali* (page 44) both refer to the same plant, i.e. *Bombax malabaricum* or more correctly *Salmalia malabarica* (*Indian Forester*, 1950. 76, 139) but two different specific names have been used for this plant.

While much of the information about plants referred to in this book is not only interesting but valuable, it is difficult to overlook the large number of typographical errors which have partly eluded the attention of the author. Some of these have of course been listed in an errata slip attached at the end of the book. A few more may be mentioned with the hope that these would be corrected and wherever possible modern botanical names given in the next edition of the book. The wrong names, as published in the book, are given first. These are followed by the correct names within parenthesis :

Lida cardifolia (*Sida cordifolia*), *Seecarpus anacardium* (*Semecarpus anacardium*), *Ellattaria cardamomus* (*Elettaria cardamomum*), *Colocassia* (*Colocasia*), *Glelina arborea* (*Gmelina arborea*), *Sansiveria roxburghii* (*Sansevieria roxburghiana*), *Clypea hermandifolia* (*Stephania hernandifolia*), *Carnea arborea* (*Careya arborea*), *Guilandiua bonducella* (*Guilandina bonducella=Caesalpinia bonducella*), *Trewia nudifera* (*Trewia nudiflora*) and *Dalbergia ougeninansis* (*Dalbergia ougeinensis=Ougeinia dalbergioides*).

Inspite of these apparent drawbacks, which I am sure would be attended to in the next edition, there is no doubt that the present book may be considered as a important publication in a subject in which thousands of persons are interested and in which there are only a few critical workers. Very rarely do we find in a botanist or agricultural scientist such a degree of interest and knowledge of Sanskrit as in the case of the present author. The combined knowledge has been admirably utilised in the preparation of this book. The book is recommended to the agricultural historical and other institutes as well as for general libraries. (D.C.)

SAMPLE SURVEYS OF CURRENT INTEREST—FOURTH REPORT

(Published by Statistical Office of the United Nations, New York, 1952, Price 50 cents)

THE present publication includes brief descriptions of sample surveys recently completed or in progress in a variety of fields in some 18 countries of the world. The general purpose of these periodical reports is to assist those interested in the application of modern sampling techniques by making available in a summary form the experience gained by various statisticians and statistical organisations. The reader would be interested to find from the present report the wide range of topics covered by modern sample surveys. It includes descriptions of surveys on such diverse subjects as population, labour, production of handicrafts, buildings, refugees, forests, agriculture and live-stock, etc. From the point of view of a statistician engaged in sampling in a specific field the information given is, however, too sketchy. For example, no indication is available of the accuracy attained in most surveys. There are, of course, the source publications given at the end of the summary for each country and the interested statistician may pursue these sources. The re-arrangement of the material by field such as population, labour, agriculture, etc. rather than by countries might make the present summaries more convenient for reference. (V.G.P.)

MGIPC—M—4 AR/53—13-11-53—880.

The Editorial Board in its work of examining papers received for publication, is assisted in an honorary capacity by a large number of scientists working in various parts of India.

Editorial communications including books and periodicals for review should be addressed to the Secretary, Indian Council of Agricultural Research, Publication Section, New Delhi.

Communications regarding subscription and advertisements should be addressed to the Manager of Publications, Civil Lines, Delhi.

Instruction to Authors

Articles intended for *The Indian Journal of Agricultural Science* should be accompanied by short popular abstracts of about 330 words each.

In the case of botanical and zoological names the International Rules of Botanical Nomenclature and the International Rules of Zoological Nomenclature should be followed.

Reference to literature, arranged alphabetically according to author's names, should be placed at the end of the article, the various references to each author being arranged chronologically. Each reference should contain the name of the author (with initials), the year of publication, title of the article, the abbreviated title of the publication, volume, and page. In the text the reference should be indicated by the author's name, followed by the year of publication enclosed in brackets; when the authors name occurs in the text, the year of publication only need be given in brackets. If the reference is made to several articles published by one author in a single year these should be numbered in sequence and the number quoted after year both in the text and the collected references.

If a paper has not been seen in original it is safe to state original not seen. Sources of information should be specifically acknowledged.

As the *format* of the journal has been standardized, the size adopted being crown quarto (about $7\frac{1}{4}$in.$\times 9\frac{5}{8}$ in. cut), no text figure, when printed should exceed $4\frac{1}{2}$ in.$\times 5$ in. Figures for plates should be so planned as to fill a crown quarto page, the maximum space available for figures being $5\frac{1}{4}$ in.$\times 8$ in. exclusive of that for letter press printing.

Copies of detailed instructions can be had from the Secretary, Indian Council of Agricultural Research, New Delhi.